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ABSTRACT

This document contains the abstracts of most of the papers, symposia, and poster sessions presented at the 62nd Annual Conference of the National Association for Research in Science Teaching (NARST). Subject areas addressed include: teacher preparation; science, technology and society; classroom research, elementary science; process skills; curriculum and instruction; misconceptions; achievement; education policy; problem solving; analytical studies; interpretive research; gender differences; attitudes; teacher characteristics; evaluation and assessment; learning; inservice teacher education; science laboratories; and microcomputers. (CW)

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PREFACE

The SMEAC Information Reference Center for Science, Mathematics, and Environmental Education has cooperated with the National Association for Research in Science Teaching to provide abstracts of most of the papers presented at the 62nd annual conference in San Francisco, CA., March 30 - April 1, 1989.

All persons who had papers or symposia accepted were invited to submit abstracts for inclusion in this publication. Some editing was done by the ERIC staff to provide a general format for the abstracts.

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LOCUS OF CONTROL AND SCIENCE RELATED ATTITUDES: A COMPARISON OF HIGH SCHOOL AND COLLEGE STUDENTS

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Affective learning outcomes identified in science education as "scientific attitudes" are receiving attention from a number of science educators wishing to improve the attitudes of the public towards science and technology. Designing and evaluating curriculum for affective objectives is in itself difficult, but particularly for science teachers who are accustomed to and most comfortable in dealing with cognitive objectives. Even more difficult is to design curriculum to maximize learning outcomes in the affective domain by including knowledge about the individual differences of learners. For the science educator who wishes to include affective objectives in the design of science curriculum, the problem becomes one of identifying particular characteristics of learners which impinge upon their acquisition of affective outcomes in science.

We postulated that the construct of locus of control is an individual difference which mediates the acquisition of science-related attitudes. Julian Rotter defined the construct as the orientation of an individual towards causation in his/her own personal life, and Mary Budd Rowe applied the construct to science education by developing the term "fate control." Rowe characterized "bowlers" and "crapshooters" as individuals exhibiting many of the characteristics of Rotter's internals and externals, respectively. Further, Rowe postulated that the bowler's orientation might be developed in disadvantaged elementary school children through early science experiences employing inquiry strategies.

The objective of this study was to acquire information about the nature of the relationship between locus of control and specific affective outcomes in science in high school and college students. High school and college students (n = 289) from a southern New Mexico community were administered Rotter's I-E Scale and the Test of Science Related Attitudes (TOSRA) in the spring of 1988. SAS was used to calculate means and standard deviations for both instruments and Pearson correlation coefficients for the I-E Scale with each of the subscales of the TOSRA. The TOSRA was subjected to a principal components factor analysis with varimax rotation.

The results of the factor analysis of the TOSRA suggest that the subscales of the TOSRA be restructured to include four dimensions rather than the seven outlined by Fraser. Our correlation of Rotter's I-E Scale with Fraser's subscales indicated that the subjects with an external locus of control had more negative attitudes toward science than internal subjects. Particularly noteworthy was the number of significant correlations in the universtiy subjects (6 out of 7), as compared with the high school chemistry (3 out of 7) and high school biology (1 out of 7) subjects.

The finding that locus of control correlates significantly with six of seven subscales at the college level leads us to speculate about the effects of intervention on younger students, where locus of control does not appear to be as strongly related to scientific attitudes. Educationally significant questions relate to what types of intervention are appropriate and when they might occur to optimally influence the development of science related attitudes in learners. We suggest research examining the effects of exposure to inquiry learning environments in upper level high school science classes, where students experience the rationality, predictability and causality of science. Inquiry may, in fact, be more effective in enhancing the development of internality and science related attitudes in these students than in students in lower grades.

DEVELOPMENT AND APPLICATION OF A SEMANTIC DIFFERENTIAL SCALE TO ASSESS HIGH SCHOOL STUDENTS' ATTITUDE-INTENTION-BEHAVIOR INVOLVEMENT WITH NUCLEAR ENERGY ISSUES

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Nuclear attitudes have typically been measured by summated rating, or Likert, scales. Recent researchers have sought to apply the technique of semantic differentials to the measurement of attitudes. A summated rating scale would be useful in conducting studies relative to the application of the Theory of Reasoned Action to explain individual's attitudes about nuclear energy.

The purpose of this study was to develop a semantic differential scale to measure attitudes toward nuclear power plants. Validation was provided through correlations to an existing validated test, the attitude scale of the Nuclear Assessment Battery, and by a known-groups procedure.

The results of the study show that the semantic differential technique can be used to easily and accurately assess attitudes toward nuclear energy.

ATTITUDES TOWARDS A SIMULATION BASED CHEMISTRY CURRICULUM FOR NURSING STUDENTS

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Chemistry anxiety exists amongst nursing students as well as students of other allied health professions. The causes for this anxiety may be attributed to three factors: chemistry is perceived as difficult, involves a multitude of facts, and is not connected to reality. There is no miraculous solution to this cognitive and motivational anxiety problem. Nevertheless, a curriculum with a simulation format has been developed that helps Israeli nursing students cope with the obstacles of learning chemistry. It is enhanced by intensive written exercises and manipulative teaching aids. A careful selection of only those topics that are necessary for understanding the principles in the more advanced courses, e.g., pharmacology, diminishes the number of facts involved in the study of chemistry to a minimum. Relevance to nursing is obtained by introducing a varied selection of medical and nursing case studies, i.e., simulations of real life situations. Examples include revival of a patient hurt in a traffic accident, and the diagnosis of metabolic acidosis by testing the pH of the blood.

Pre and post test open attitude questionnaires were used to assess the students' feelings towards chemistry before and after they studied chemistry using the simulation-based chemistry curriculum. At the end of the course students also responded to a questionnaire consisting of seven Likert type items aimed at assessing their perceptions regarding the curriculum according to what they had studied.

Analysis of the open attitude questionnaires has shown that most students welcome the project. The number of positive items in the posttest was greater than in the pretest, while the number of negative items was smaller, indicating an increase in the positive attitude towards chemistry. According to the Likert type items, most students indicated that the learning material was clear to a great extent and helped them understand the various subjects. The simulated case studies embedded in the curriculum were reported by most students to have made a significant contribution to their understadning of the relation between chemistry and nursing. The majority of students thought the the textbook was both interesting and enjoyable. Students were also asked to evaluate the degree of difficulty of each chapter in the book. For most of the chapters the findings were coherent with the results of their achievement post test. The positive attitude towards the curriculum can be attributed, at least in part, to the fact that the approach establishes the link between the abstract ideas presented by the "pure" chemistry and real, everyday life of the nursing students' future profession.

WORLD VIEW THEORY AND SCIENCE EDUCATION RESEARCH: FUNDAMENTAL EPISTEMOLOGICAL STRUCTURE AS A CRITICAL FACTOR IN SCIENCE LEARNING AND ATTITUDE DEVELOPMENT

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Some of the most interesting work currently being done in science education research is with scientifically misconceived ideas about the causes and mechanisms of natural phenomena or, as it is more simply called, misconception research. As in any avenue of research, certain assumptions are required. Though not stated explicitly, it can be inferred from the corpus of misconception research that an assumption of homogeneity among students is made, even where there is gender, racial, and cultural diversity among students. Specifically, it is assumed that students come into secondary and college science classes with relatively homogeneous, fundamental views of the natural world capable of assimilating and valuing modern scientific understanding when science knowledge is presented in traditional enquiry fashion. Therefore, researchers attempt first an exact identification of the misconception, and then to find methods for supplanting it with accurate scientific understanding. Generally they do not ask, "Is it possible that this scientifically misconceived idea is a logical deduction from some fundamental view of nature held by the student?" This question would indicate that the researchers suspect that more is at issue than factors of pedagogy and student intelligence.

This paper is a theoretical work on the fundamental, epistemological structure of the mind, or more simply, world view. The researcher believes that it is a mistake to assume that there is worldview homogeneity in the typical classroom and that this assumption retards a more comprehensive understanding of factors that lead to science achievement and positive science attitudes. Furthermore, the researcher suspects that the assumption of worldview homogeneity shields the root causes of the well documented recalcitrance of misconceptions to standard science pedagogy. While most would grant that in ethnically diverse classrooms a prima facie case can be made for worldview variations as a factor in the education process, the principal assumptions in this paper are that the students in many, if not all, science classrooms have subtle worldview variations; and that these variations are in important factor in science achievement and attitude development among students. Without these assumptions one would not embark on this avenue of research. Having made them, the research thus derived will ultimately speak to their veracity.

Specifically, the purpose in this paper is to present a logico-structural model of world view and to discuss its potential for use in science education research. Although this paper begins with a focus on science misconception research, it is intended that the relevance of worldview theory to other research interests become evident. This paper differs from many others in science education research in that it assumes studies in anthropology can be as important to science education as the history and philosophy of science have proved to be.

IMPLEMENTING AN EFFECTIVE ELEMENTARY SCIENCE PROGRAM: THE PROCESS AND EFFECT ON STUDENT ATTITUDES

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The 1980s have been exciting times for science educators. Adding to the excitement is the realization that students who entered kindergarten during the Fall of 1988 will be the first high school graduates in the 21st Century. Thus, responding to the question, "Are students being provided with the scientific and technological literacy essential for life as productive citizens in the 21st Century?" is today's curricular imperative.

In March of 1987, the Chesire Public Schools (CT) established a K-12 science committee to address the above question. Internal audits revealed a local situation that paralleled the recent national image portrayed by "The Science Report Card...". During the next six months the committee developed a mission statement; a rationale for teaching science; program goals and objectives; a plan for identifying, developing, and piloting curricular materials; a rationale for staff development and program implementation; and, the evaluation component associated with the first year pilot. The committee decided to begin the curriculum revision process at the elementary level in order to allow for subsequent curricular development and continuity at the middle school and high school levels.

Thus, by September 1987, the committee had identified curricular materials to pilot and had begun the process of local curriculum development. During the 1987-88 academic year, Cheshire's ScienceQuest program was piloted in selected K-6 classrooms. Student attitudes toward science were assessed at the completion of the first year of the pilot.

This report will focus upon the processes associated with the identification, development, and implementation of curricular materials; the nature of administrative support and the associated staff development; as well as, the results of the attitudinal assessment by treatment, treatment x gender, and treatment x grade.

TEACHER ABILITY TO TOLERATE AMBIGUITY: A NECESSARY REQUIREMENT FOR INCORPORATING NOVEL TASKS IN PHYSICS INSTRUCTION

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Using an interpretive research methodology, three researchers observed one teacher and his class of Year 11 physics students on a daily basis for one semester. The focus of this paper is to describe the manner in which the physics teacher incorporated novel tasks into his teaching programme and to describe the features which enabled those novel tasks to be successful teaching episodes. Novel tasks or understanding tasks are described by Doyle as being high in both ambiguity and risk. This paper describes how the physics teacher taught six laboratory activities, namely: measurement of small distances; measurement of solid/and liquid/ densities; measurement of specific heat of metals; and three investigations about latent heat, waves and gas laws.

Observations made about these novel tasks provided information congruent with that described by Doyle together with further elaboration of how science teachers can incorporate novel tasks in their teaching repertoires. The study details eight assertions related to how the physics teacher organized and managed the teaching of the laboratory experiments and provides three major conclusions relating to the educational importance of the study. First, in order to incorporate novel tasks in the teaching programme a teacher needs to have a strong content background and be confident to withstand the problems which arise as a result of students initially being hesitant and confused about the required task. Second, the teacher incorporating novel tasks into a teaching programme needs to do so in a limited manner since such tasks would appear to be initially stressful for both students and teacher. The teacher especially needs to have an ability to tolerate ambiguity and not solve students' conceptual problems at the outset of a lesson. Third, the teacher needs to allow time in the experimental work for students to do additional unanticipated activities.

ANALYSES OF COMMUNITY COLLEGE SCIENCE FACULTY NEEDS AND CONTINUING SCIENCE EDUCATION PROGRAMS DESIGNED TO ADDRESS THESE NEEDS

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In the last ten years, funding for community and junior colleges has been severely limited. Although huge numbers of students can be found in these institutions, opportunities for outside funding from both private and public sources are inadequate.

This study determined the needs of community college science faculty members and developed two continuing education programs. These science education programs were analyzed and their effectiveness determined through a variety of avenues.

The sample consisted of the college administrators and science faculty at the nine community and junior colleges in the Texas Gulf Coast Area. These nine two-year colleges serve over 200,000 students per year and have a total of 154 science faculty. All of these faculty members were fulltime and had an average of 10 years teaching experience.

To assess the needs of community college science faculty of the Texas Gulf Coast area, a needs assessment was conducted among the administrators and faculty of the nine community colleges in this region of the country. The results mirror other national surveys that indicate that among two-year science faculty workshops concerning both content and pedagogical areas are of primary importance.

Based upon these needs, two programs were developed. One focused upon teaching strategies and using classroom interaction videotape analysis to assess one's teaching approach. Two three-day workshops were used to attempt to change faculty members' teaching style. Case studies were done on the participating faculty in this program. The other focused upon using research scientists to provide eight seminars, four symposias and semester-long research fellowships. The two programs differed in content, time spent in program and outcomes. Controls were used in both scenarios. Course grade was used to assess achievement and appropriate measures were used to assess attitudes toward science. Videotaping and interviews were used to assess the faculty's attitude toward the programs and their teaching styles. Appropriate statistical analyses were used. These include more descriptive treatments and empirical treatments such as the analysis of variance.

The results of this study point to a number of conclusions. First, community college science teachers voice concerns about both their needs of content updating and changes in teaching style. Second, certain program designs may be more effective in creating changes. To create changes,

time becomes a critical factor. Updating of content knowledge was relatively painless to accomplish, requiring individuals just to acquire more knowledge. However, modifying one's teaching style may be more difficult and require more concentration on the part of the teacher. This difficulty is reflected in the faculty's level of frustration during these programs.

AN INVESTIGATION OF THE RELATIONSHIPS AMONG SCIENCE ANXIETY, EFFICACY, TEACHER EDUCATION BACKGROUND VARIABLES, AND INSTRUCTIONAL STRATEGIES

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This study was designed to investigate the relationships among anxiety toward teaching elementary science, science teaching efficacy, elementary teachers' educational background, and instructional methods employed in the elementary science classroom.

Many elementary teachers have poor attitudes toward teaching science, feel inadequately prepared to teach science, give science little time in the curriculum, and use instructional strategies which are not consistent with learning theory, research on science teaching, or science educators' views on good science teaching.

Historically, educators have not agreed upon the necessary proportion of science content courses or methods courses for the preparation of elementary teachers. Recent criticisms of teacher education programs (i.e., the Holmes, Carnegie, and National Science Board reports) cite lack of science and mathematics content for elementary teachers as a problem.

Research on anxiety and self efficacy suggest that behaviors, levels of persistence at a task (such as teaching), and degree of risk taking and innovation are related to degrees of anxiety and self-efficacy. Elementary teachers' perceptions of science teaching ability, science teaching efficacy, and levels of anxiety may be related to past experiences - the amount of content background and the amount of methodological preparation. Levels of science teaching anxiety and science teaching efficacy may be related to teaching behaviors such as instructional methods utilized in the classroom. Perhaps, teachers who cite factors such as inadequate facilities, lack of time, school organization, or few resources as reasons for little or poor science instruction are teachers who have a high level of anxiety toward teaching science and a low level of efficacy toward science teaching.

Over one hundred inservice elementary teachers of grades 1-6 were studied to examine these issues. Each teacher completed six questionnaires aimed at measuring science teaching anxiety, science teaching efficacy, science content preparation, science methods preparation, and instructional strategies used in the teaching of science.

The data from these questionnaires were used to address the following research questions:

-Is there a significant relationship between the two constructs, science teaching anxiety and science teacher efficacy?

-Is there a significant relationship between level of science teaching anxiety or science teaching efficacy and science content background?

-Is there a significant relationship between science teaching anxiety or science teaching efficacy and science methodology background?

-Are there significant relationships among science teaching anxiety, science teaching efficacy, and actual utilization of instructional methodologies?

Pearson correlations were computed during the pilot stage of this study. The preliminary results indicated a significant inverse correlation between science teaching anxiety and science teaching efficacy, but other correlations between science teaching anxiety and educational background or instructional strategies were unclear, perhaps due to the small sample size in the pilot.

THE NATURE OF TEACHER VERBAL EXPLANATIONS IN JUNIOR-HIGH SCIENCE CLASSROOMS

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The purpose of this study was to explore and describe some of the types of explanations used by junior high science teachers in a natural classroom setting. Twenty teachers belonging to 13 different school districts were observed intermittently over a period of six weeks. During those observations, technological records in the form of audiotapes were obtained and supplemented with field notes. Tapes were transcribed and instructional content was analyzed using an open system in which categories were 'induced' from the transcribed text. Recurring regularities of explanatory patterns were sorted into types which were being continuously applied and refined against the data. Those types were later checked for validity and internal consistency. In the paper, the authors report on the initial findings of the study, and discuss the implications of those findings to in-service and pre-service teacher education programs.

ESTABLISHING THE PERCEIVED NEEDS AND STATUS OF SECONDARY KANSAS SCIENCE TEACHERS

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In order to make science teacher preparation, both preservice and inservice, more effective, it is essential that we first analyze the perceived needs and current status of the target population. This study was designed to assess the perceived needs and status of secondary science teachers in Kansas. Secondary science teachers, as well as teachers as a whole, have received criticism regarding their competencies and their lack of accountability in terms of student science achievement. If we are to assist teachers in their instructional improvement, we must design both preservice and inservice programs that meet the needs of the teachers to be involved.

The instrument used in this study, "Kansas Science Teaching Needs Inventory," was developed through modifying a survey instrument by Padilla, et al. Demographic items were changed to reflect the special characteristics of Kansas schools, e.g. school size, grade level breakdown, etc. In addition, items were added to assess the viability of various graduate course offerings, preferred times, and inservice topics. The instrument was four pages in length and consisted of the following sections:

1. Personal Information;
2. Teaching Strategies;
3. District Information;
4. Status of Science Educators;
5. Inservice Needs;
6. Science Curriculum; and
7. Materials.

The instrument was mailed to all secondary science teachers in Kansas, after purging the State Department of Education mailing list of duplicate entries. A total of 1,100 surveys was mailed. Of these, 405 were returned. No follow-up mailing was done.

The study indicated that there are similarities between rural and non-rural teachers. One of the highest concerns was in regard to the use of microcomputers. Also, teachers were highly interested in taking science content courses. It was also clear that teachers are not using the latest innovations and instructional techniques. Science teachers did express a strong interest for inservice in science content, instructional materials and new teaching strategies, with high preference for summer course offerings.

A RESEARCH-BASED DESIGN FOR INSERVICE TRAINING IN MARINE SCIENCE FOR PRIMARY, MIDDLE SCHOOL AND HIGH SCHOOL

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In general, inservice training is neither theoretical, research-based nor teacher-driven. This is particularly true from the university position where graduate programs provide most of the inservice opportunities. Inservice education has been characterized as having a relatively private, eclectic, and diffuse character. There is little research as a basis for understanding its contribution to teachers' knowledge, competence, and enthusiasm for teaching. Without this theoretical base, programs are difficult to evaluate.

Some research for inservice design relates effectiveness of the program either directly to the teachers or as passed on to the students. However, the implementation of research results to inservice programs does not appear to be commensurate with the amount of staff development funds and time devoted to inservice activities. With more teachers staying in the workforce, inservice training becomes more important to maintaining a high quality of education.

A statewide, K-12 survey was conducted in North Carolina with one of the goals to develop research-based inservice priorities for marine education. Of 350 teacher respondents, 86% taught some marine concepts in their classes. The criteria for accessing information differed significantly among primary, middle grade and secondary teachers. One part of the survey asked for teachers' perceptions on marine topics and their confidence in teaching those topics. Results were compared with similar data from Mississippi and Minnesota.

Analysis of the survey data shows that additional inservice training opportunities are needed for primary and middle grade teachers. This inservice should be short in length, executed at the school and involve videos to allow teachers, and later students, to "see" the environment. Primary teachers seem to want materials ready to use with very little involvement on their part. This is probably due to their lack of confidence and training in the sciences.

Secondary teachers appear to be more mobile and more able to manipulate materials and curriculum for their own use. Inservice activities in coastal settings are more desired.

Other results indicate specific topics where teachers perceive themselves to be weak. This information provides a guide to the content of the inservice program.

In conclusion, extensive sampling of teachers allows inservice programs to be more teacher-driven and more responsive to their needs. However, since this type of inservice is initiated from a university base, the strengths inherent in faculty involvement and availability of materials are integrated in the program.

OBSERVATIONS RELATED TO TEACHER CONCEPT FORMATION IN AN IN-SERVICE SETTING EMPHASIZING QUESTION ASKING BEHAVIOR

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This study consolidates a number of observations of teachers in a particular institute setting designed to facilitate learning content through doing science processes and asking questions related to self-perceived conceptual difficulties.

The subjects in the study were 11 elementary school teachers from a small school district in northeast Florida enrolled in an elementary science institute, Summer 1988. The institute component required that a number of physical science concepts be covered including that of density. After an introduction to basic and integrated science processes, the teachers completed a 13 item two-tiered density inventory. A two-day treatment followed and focused on misconceptions evident on the pre-test by means of strategies to encourage and promote teachers' question asking behavior.

Pre-test results yielded the following error patterns:

(1) confusion of mass and volume of solids and liquids;
(2) confusion of mass and density of solids and liquids;
(3) inability to conceptualize gases having mass and density;
(4) difficulties in conceptualizing more gas particles in a given space;
(5) difficulties in performing density problem calculations.

Post-test results showed significant improvement, indicating that several teachers corrected misconceptions. However, some teachers either (1) adhered to original misconceptions or (2) changed to an incorrect response by either giving a new incorrect response or changing a pre-test correct response to a post-test incorrect response.

Adult teachers tended to (1) increase the number of questions which they ask; (2) become more skillful at question asking, especially questions which lead to productive action; and (3) develop confidence in their own ability to challenge their understanding/explanation of phenomena.

THE BEGINNING SCIENCE TEACHER: A CASE STUDY OF CONVICTIONS AND CONSTRAINTS

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This case study examines the thoughts and actions of a second-year middle school science teacher who was part of a larger study of teachers' beliefs about science and science teaching and their influence on classroom instruction. His case is particularly useful for depicting how beginning teachers struggle with reconciling their beliefs about what they should be doing with what they believe is possible in their working environment.

Qualitative methodology was chosen for this study because it is more sensitive to the complex environment of the classroom and allows the researcher to examine unexpected events. A combination of formal and informal interviews and classroom observations were utilized for obtaining data for the study.

McGee, a 45 year-old man who has spent most of his life in the mid-west, was an eager participant in this study. We scheduled four formal interviews of about two hours duration as well as numerous informal interviews between and after classes. I observed McGee's life science class for regular-track seventh graders and his physical science class for accelerated seventh graders for about 36 hours during a seven month period.

In addition to field notes and audio-taped observations and interviews, other data were collected. These included textbooks and McGee's tests, quizzes, worksheets, and lab activity sheets. A reflexive journal containing a record of the schedule and logistics of the study, a personal diary for reflection and speculation, and a log concerning methodological decisions and rationales was kept.

Although there were many ways in which McGee taught his personal philosophy about science in his classroom, there were many other times when his expressed beliefs about what he should be doing in the classroom were not congruent with what he actually was doing.

The themes of McGee's discussion on what science teaching should be included "getting dirty," "messing around," and "going off on tangents." Yet there was very little of this happening in his classroom. Most of the instruction centered on vocabulary words from the textbook or dissection labs in which students were to find and label many structures.

I believe there were at least three obstacles that inhibited McGee from utilizing instruction congruent with his belief that real science learning occurs when students are "messing around." These include: (1) he was unable to circumvent overwhelming institutional constraints, (2) he was learning the science content as he was teaching it, and (3) he also believed that students need to be given structure and procedures to learn in a classroom setting. Evidence for each of these constraints and their interaction with McGee's beliefs will examined.

EFFECTS OF ENCOURAGEMENT OR DISCOURAGEMENT FOR USING HANDS-ON SCIENCE ACTIVITIES UPON TEACHING STYLE

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Observations in schools by college supervisors indicate a gap between what a teacher knows on a theoretical level and what is actually done in classrooms on a practical level. Frustration occurs when pre-service teachers are instructed in the importance and correct uses of hands-on activities, especially in science, but these lessons and ideas are not transferred into a field setting. Why does this occur? What encouragement or discouragement for using hands-on activities actually impacts on a teacher's style of presentation? When does this encouragement or discouragement occur? Can preservice instruction in methodologies play a stronger role in the actual presentation styles observed in classrooms?

This study was to determine where teachers perceive encountering encouragement or discouragement for lessons involving hands-on activities in science, how strong this encouragement or discouragement was, and the effect this has had on their teaching style.

A six-part questionnaire was developed to determine the possible sources of encouragement or discouragement for using hands-on activities in the elementary science classroom. A Likert scale was used on four of the sections. The questionnaire took approximately 20 minutes to complete.

Having information on the role teachers perceive this encouragement or discouragement plays on their teaching style, whether they receive more of one than the other, and where they perceive it comes from will allow preservice methods classes and inservice workshops to utilize strategies specifically developed to counteract the problem areas. This should result in strengthening the transference of methodologies from university classes to public schools and allow for more theory to be put into practice.

THE DESIGN OF A COMPUTER-BASED SCIENTIFIC PROBLEM SOLVING TEST FOR SECONDARY STUDENTS

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One of the difficulties in determining the effectiveness of instructional methods used to teach scientific problem solving at the secondary level has been in developing a test that measures the ability of the student to design an experiment and to interpret the results of the application of that design in a realistic setting. Paper and pencil tests are limited. They cannot test the application of problem solving skills in an interactive setting. The use of computer simulated laboratories to test student experimental design technique and scientific modeling skills has great potential. This paper describes the development and pilot testing of a computer-based assessment instrument designed to measure the biological problem solving skills of secondary students. Results of both pilot tests and small scale trials are summarized. The purposes of a large scale field test are described. The presentation of this paper will include a brief demonstration and discussion of the nature and operation of the instrument.

ENHANCEMENT OF SCIENCE CONCEPT UNDERSTANDING THROUGH VIDEODISK TECHNOLOGY: IMPLICATIONS FOR ELEMENTARY PRESERVICE METHODS COURSES

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Recent research has repeatedly targeted lack of science knowledge as a major factor inhibiting both effective science instruction in elementary schools and strong teacher preparation programs. Despite efforts to significantly improve science teaching methods, minimum undergraduate science requirements severely limit the science knowledge teachers are able to apply in gaining skills necessary for science instruction. One promising approach to the problem of enhancing preservice teachers' science knowledge is the utilization of videodisk educational technology designed to teach core science concepts using direct instruction principles. To explore the effect of expanding the science knowledge of preservice teachers, this study incorporated the use of videodisk instructional materials in earth science as an integral part of an elementary methods

course. In the study, 25 preservice elementary teachers first previewed core science concepts presented through videodisk technology and then discussed the relationship of the concepts to science methods, including hands-on activities, open ended questioning, and science, technology and society (STS) issues. The effect of the videodisk-based program was assessed by comparing preservice participants to controls enrolled in otherwise comparable science methods courses on amount of science knowledge gained, attitude toward science instruction, and instructional problem-solving skills using STS issues.

AN ANALYSIS OF THE MOST USED SCIENCE TEXTBOOKS IN SECONDARY SCHOOL IN THE UNITED STATES

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This study provides an analysis of twelve science textbooks considered by Weiss' 1978 national survey as the most frequently used in the secondary schools in the United States. Six aspects were examined in each of the textbooks which included: (1) General physical features of the book, (2) Terminology, (3) Readability, (4) Laboratory activities, (5) Questioning styles in narrative, (6) Two aspects of scientific literacy, namely, nature of science, and interrelationships of science, technology and society. Initial findings include: (1) Considerably large amount of page space (in percentage of total text) has been devoted to the illustrations, especially at junior high level; (2) Extraordinary numbers of terms have been emphasized in the biology text when compared with text of other disciplines and/or grade levels; (3) The readability level of both chemistry textbooks exceeds the intended reader grade level; (4) Two NSF supported curriculum programs have the highest percentages of the lowest level of openness/discovery; (5) Questioning style in narrative tends to be rhetorical across all grade levels; (6) Concerning the dimension of the nature of science of scientific literacy, less than 3% of the total narrative page space has been devoted to the relevant information expect one NSF supported program; (7) Concerning the interrelationships of science, technology, and society (STS), the coverage of relevant information is greater in junior high science textbooks than in the high school science textbooks. With only one exception, this coverage of STS information is less than 7% of the total narrative page space in all the textbooks.

IMPLEMENTING CHANGE IN SECONDARY SCIENCE READING AND TEXTBOOK USAGE: A DESIRED IMAGE, A CURRENT PROFILE AND A PLAN FOR CHANGE

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Most secondary science courses in North America are designed around textbooks as the primary or exclusive source of information about the content or processes of science, and most science teachers focus their instruction around a single text. Although there are many serious issues raised by the overwhelming reliance on text-based teaching/learning in science, the text-based approach is likely to remain a dominant instructional method in most secondary science classes. Furthermore, while a large variety of approaches are possible for teaching with science texts, until very recently, little has generally been done to prepare science teachers regarding effective uses of textbooks and for teaching content reading skills in the science classroom.

This study attempted (1) to describe a desired image for science reading instruction and effective use of science textbooks based on current reading research results, (2) to describe the current profile of science reading instruction and use of science textbooks in secondary classrooms, and (3) to propose the first steps for planned changes in secondary science reading instruction and uses of science textbooks.

In an attempt to describe the desired image of science reading and textbook usage a survey of the reading literature was conducted. The literature survey and resulting distillation yielded 20 global traits of an efficient, successful science reader.

In an attempt to assess the present status of science reading instruction and textbook usage by secondary science teachers, 428 secondary science teachers in British Columbia, Canada were surveyed. Completed Science and Reading Questionnaires were returned by 215 teachers. The questionnaire explored teachers' attitudes toward and knowledge about science reading and science reading instruction. Fifteen respondents from a pool of 98 volunteers were also interviewed and their science teaching observed. The interviews were divided into pre-observation and post-observation structured protocols. The data reported here relate exclusively to what teachers believed to be important purposes of text and text features, what they did to improve science reading skills and comprehension, and how they used science textbooks in secondary science classes.

An analysis of the desired image and current profile identified five main categories of instructional practice and teacher attributes that influence metacognitive and cognitive skills development in secondary science readers and may be sensitive to change: (1) teachers' knowledge about science

education, science text, and science reading; (2) teachers' knowledge about science textbooks; (3) instruction aimed at improving students' background knowledge and schema development; (4) direct reading skills instruction; and (5) teacher awareness of, knowledge about, and assessment of reading comprehension.

THE EFFECTIVENESS OF DYNAMIC MODELS ON CONCEPTUAL SHIFTS IN COLLEGE STUDENTS

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Contemporary researchers often refer to the information processing paradigm to explain the relative ineffectiveness of contemporary instructional techniques for modifying incorrect scientific concepts that students often bring to a learning situation. As a result of this research, instructional procedures have been developed that maximize the chances that conceptual change will occur. It is within the context of this conceptual change framework that this study takes place.

Commonly accepted conceptual change strategies identify specific basic conditions that need to be met before students' existing mental constructs are changed. It is the authors' contention that the attention to imagery inducing procedures would make these strategies significantly more effective. The major hypothesis of this study is that, particularly for abstract concepts, the imposition of a mental image by the presentation of a dynamic model would result in higher achievement than the presentation of a verbal or static model representing the concept. The laser videodisc was used to generate the appropriate images in this study. The technology affords the ease of presentation that makes the results of this study potentially more generalizable.

The study uses an aptitude-treatment-interaction model that probes the main effects of visualization capability and treatment as well as the interactions between these effects. Visualization, as it is defined in this study, refers to the ability to manipulate mental images and was measured by the Visualization test from the Kit of Factor-Referenced Cognitive Tests. The study consisted of intact classes of college students enrolled in introductory and general science courses. The imagery enhanced conceptual change strategy was given to half of the randomly selected classes. The remaining classes were presented with an imagery free conceptual change strategy. The Kinetic Theory was the topic presented to both classes. The dependent variable was measured by a modification of the Test about Particles (Fazio). A 2x2 ANOVA was utilized to analyze the results.

EXAMINATION OF HIGH SCHOOL CHEMISTRY TEXTBOOKS

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Although only about one fourth to one third of the student population in high school takes chemistry, this is an important course to the science education of our youth. Chemistry textbooks, in particular, are a significant part of chemistry education. The textbooks are not only used by the individuals teaching chemistry but they are used by other science teachers as reference texts in physical science, biology, and earth science. The various aspects of scientific literacy that are conveyed in these textbooks have a direct impact on many science teachers as well as on their students. If chemistry textbooks place heavy emphasis on descriptive chemistry, for example, chemistry may be viewed as a course where one must memorize many terms. If they place heavy emphasis on principles and laws, chemistry may be viewed as a very abstract discipline and perhaps difficult to learn.

Science textbooks have long been an item of interest and concern among science educators. These teaching aids are used widely and frequently in science course instruction. Thus, they convey the information that students receive and influence how students perceive the scientific enterprise. An overreliance on these textbooks often results in an overemphasis on terminology and vocabulary, which can present a false impression of the scientific enterprise.

The purpose of this study was to examine the content of many high school chemistry textbooks for their emphasis on the following aspects of scientific literacy: (1) science as a body of knowledge, (2) science as a way of investigating, (3) science as a way of thinking, and (4) the interaction among science, technology, and society.

As expected, these chemistry textbooks stress science as a body of knowledge and placed little emphasis on science as a way of thinking and the interaction among science, technology, and society. This imbalance in curriculum emphasis and lack of importance on the true nature of science raises the question as to whether high school chemistry will make its contribution to the improvement of scientific literacy in our society and encourage more students to enroll in high school chemistry courses.

A STUDY OF SCIENCE ACTIVITIES OCCURRING IN A WHOLE-LANGUAGE CLASSROOM

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This study was undertaken to identify teacher behaviors occurring in a whole-language classroom as the students were involved in science activities. In addition, a second purpose was to describe how children do science in a whole-language class. Lastly, the conjecture that students experiencing science in a whole-language setting (as well as other subjects) exhibit a greater degree of cognitive development than a similar group of students receiving instruction in a more traditional fashion.

Data collection was through participant observation of teacher-student interventions. Video taping was done periodically, and these were used to confirm and modify future observations. The three participant observers plus the classroom teacher interpreted the participant observer's notes. The last source of data was the students themselves.

To determine cognitive development a paper-and-pencil measure was administered to the class receiving the whole-language instruction as well as to another intact class, the latter receiving instruction through more traditional means, both at the beginning and the end of the study.

The results from the paper-and-pencil measure indicated that the students in the whole-language class exhibited a statistically significant increase in cognitive conceptual ability, whereas the class receiving more traditional instruction did not.

The teacher in the whole-language classroom exhibited a range of cueing behaviors as she changed teacher roles. She acted as if the students were competent, sensible, and well-intentioned. The teacher used minimal guidance. The teacher's directions were effective. Students were always involved in activities which were complicated and yet success generating. Success in this class was not only judged by the fact that students had successfully accomplished a task, but that they would think the task important and worth accomplishing.

TECHNOLOGY AS A TOOL IN ELIMINATING STUDENT MISCONCEPTIONS: IMPLICATIONS FOR SCIENCE INSTRUCTION

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A study designed to assess the extent to which technology might be used to eliminate student misconceptions about concepts in astronomy was designed. The study was founded in the research on alternative frameworks that has received considerable attention in the recent research literature.

The subjects were 84 fifth graders who had received no prior instruction in concepts dealing with the earth's seasons, night and day, and phases of the moon. The subjects were randomly assigned to four groups. The first was instructed using interactive computer software, the second received traditional instruction from a teacher, a third used the technology in combination with the teacher discussion, and the fourth received no instruction. A posttest designed to assess the subjects' knowledge of the content presented in each lesson, as well as prominent misconceptions was prepared, validated, and administered.

Subjects receiving each form of instruction scored significantly higher than the control group on measures of knowledge, and subjects using technology alone as well as technology in combination with teacher instruction both scored significantly higher than those receiving teacher instruction alone. There was no significant difference in measures of knowledge between the technology-only group and the technology plus teacher instruction group. However, subjects taught with interactive technology in combination with teacher instruction had fewer misconceptions remaining after instruction than any of the other groups.

The results have serious implications for science teaching. The study suggests that science as traditionally taught, while increasing base level knowledge of traditional concepts, is not eliminating the misconceptions pupils acquire in elementary school. Inability to eliminate the misconceptions may result from the elementary teachers' own alternative frameworks. The use of technology in combination with instruction offers promise in moving toward a solution to the problem.

AN INVESTIGATION OF HIGH SCHOOL STUDENTS' MISCONCEPTIONS RELATING TO ATOMS AND MOLECULES

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In recent years an extensive literature has developed which indicates that the population at large, and the school population in particular, holds a wide variety of misconceptions and alternative conceptions of scientific phenomena. In some subject areas, such as physics, the literature is extensive. In others, such as chemistry, the range of concepts which has been investigated is less extensive, and in need of further elaboration. The present paper contributes to this elaboration. Two related concepts, both of fundamental significance to the study of chemistry, but for which students' conceptions are not well documented, were chosen for study. The concepts studied were those of 'atoms' and 'molecules'.

Data were obtained by administration of semi-structured individual interviews to a stratified random sample of thirty high school students of differing abilities and backgrounds in science. Fifty six misconceptions were observed and are reported. These are grouped into eleven categories relating to structure, composition, size, shape, weight, bonding and energy of molecules and structure, shape, size, weight and animistic perceptions of atoms. Some conceptions were observed which are at variance with current scientific thought but are consistent with earlier scientific views, such as those of Descartes and Havy. These are described and discussed.

THE DEVELOPMENT AND TESTING OF AN ASSESSMENT INSTRUMENT TO IDENTIFY PHYSICAL SCIENCE MISCONCEPTIONS OF PRESERVICE ELEMENTARY TEACHERS

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It is apparent from the writings coming out of misconception research that a goal of science education should be not only to teach scientific knowledge, but to design instruction so that students abandon previously-held misconceptions and construct more valid conceptions in their place. It is also clear that problems with misconceptions begin as early as elementary school and are not restricted to students. The first step in altering misconceptions in science is identifying what misconceptions the learner may hold. In most misconception research the means of obtaining information about the learner's misconception has been through individual interviews. However, the methodology of interviewing has been criticized as nonstandardized, time-consuming and of questionable reliability.

This study describes the procedures used in the development of a paper and pencil multiple choice, two-tier instrument to reliably and validly identify physical science misconceptions. The first tier of the question assesses the learners' knowledge of the concept. Responses to the second tier provide a means of diagnosing the degree and nature of the misconception.

In order to develop plausible reasons for choosing each distractor in the test of physical concepts, preservice elementary teachers were administered the first tier of the test and asked to record their reasons for the choice they made. Their responses were analyzed for patterns of shared misconceptions and reasoning. Based on response patterns some subjects were selected for unstructured tape-recorded interviews. These procedures resulted in revisions of the first tier distractors and the development of a second tier of reasoning choices.

Preliminary analysis of the data indicate that preservice teachers do share common misconceptions in the physical sciences. The results suggest that misconceptions vary in degree of complexity. The study has psychometric implications for the development and analysis of misconception testing as well as instructional use of the results of such tests.

ENHANCING THE LEARNING CYCLE WITH PREDICTION AND LEVEL THREE INTERACTIVE VIDEODISC LESSONS IN SCIENCE

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The Karplus learning cycle model has been shown to increase process skill achievement over traditional teaching methods. It can be given greater flexibility and learning power by adding the process skill of prediction. Prediction is recognized as an essential component of scientific inquiry and a terminal objective for science education research.

Extensive literature review revealed a paucity of science education studies dealing with the thinking mechanisms, teaching, and assessment of prediction. A study by Lavoie and Good considered relationships between subjects' Piagetian stage, misconceptions, and cognitive behaviors of prediction in a learning cycle lesson on water pollution. They also developed a procedural model of the prediction process. It was evident from this research that future studies are needed to examine the cognitive processes of prediction in other science subject domains, the effects of adding prediction to the learning cycle at various points, and the effects of initial conceptions (misconceptions) about the subject matter on subsequent learning and prediction.

Teaching and research centered on prediction and the learning cycle could be greatly facilitated by utilizing Level Three Interactive Videodisc Instruction (L3IVI). This new technology, which uses a microcomputer interfaced with a videodisc player, has capabilities that allow the student to view simulations of "real life" phenomena, explore a science system, and identify and manipulate variables. The computer can also pose questions, record and analyze responses, and keep a sequential record of user activity.

Thus, the purpose of this study is to investigate:

1) The cognitive behaviors of prediction in various science subject matter domains.
2) The relationship of initial conceptions (misconceptions) to subsequent predictions and learning.
3) Methods of teaching and assessing prediction in the learning cycle.
4) The use of L3IVI for teaching the learning cycle and as a research tool.
5) Further development of procedural models of prediction.

Information processing theory, which has proven quite useful for studying how people think, will provide the theoretical framework. A useful naturalistic research tool for collecting data on thinking processes is the "think aloud" interview. Think-aloud interviews are employed in this study to collect videotaped data on cognitive processes associated with students' initial conceptions (misconceptions) of the subject matter, predictions, progress through the learning cycle lessons, and use of L3IVI. Data are analyzed using qualitative techniques of verbal protocol analysis and comparative systematic analysis. Learning cycle lessons are developed and programmed into the computer using an authoring system at Wayne State University.

Poster Papers: Research on Assessement and Implementation of Projects and Programs

THE PROMOTION OF SCIENTIFIC LITERACY THROUGH INFORMAL SCIENCE EXPERIENCES IN A HIGH SCHOOL CLASS

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The paper describes an experiment with four more or less equivalent (intelligence, school achievement, social economic environment) standard 8 (grade 10) classes. Two classes were used as an experimental group and two as a control group. Materials of a teaching unit, Rockets and Space Flight, were used in the experimental group and local traditional material in the control group. The pretests and posttests consisted of: (1) A questionnaire developed by the RAU Scientific Literacy Research Project; (2) Interviews; (3) A Tamir Cognitive Preference Test. The results from the questionnaire and interviews indicate a statistically significant improvement in scientific literacy in the experimental group compared with the control group. There was also a noticeable improvement in cognitive preference in the experimental group. It is concluded that these improvements were due to the exposure to the materials in the teaching unit, Rockets and Space Flight.

SCIENCE TEACHING IN FLORIDA ELEMENTARY SCHOOLS: A PRELIMINARY STUDY

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Florida's Educational Reform Act of 1983 delineated a desired state for science K-12. Prior to this legislation there were no requirements or standards for science in elementary schools.

The purpose of this 1987 study was to determine the extent to which elementary school teachers were aware of the State's requirements and standards and were able to implement instruction to meet them. This information was intended as a data base upon which to build action plans that would move elementary science teaching toward the desired state.

The format used to present and interpret the data was a discrepancy model comparing the desired state to the existing state. Key characteristics describing the desired state were derived from three state products for Florida schools; (1) a list of Minimum Standards for Science, (2) a list of State Standards of Excellence for Science, and (3) a series of course frameworks. The description of the existing state came from respondents' self-reported data and the responses to the data from those who interact with elementary teachers.

The survey raised as many questions as it answered. For example, there was reason to question whether the teacher respondents were typical of the State's elementary teachers. The presentation will address the limitations of using written surveys to determine the condition of elementary science, the specific instrument and procedures used in this survey, and will make recommendations for follow-up studies.

OUTCOMES OF A COOPERATIVE SCHOOL-COLLEGE PROJECT INVOLVING TEACHERS AS RESEARCHERS

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Erikson concluded that educational researchers should take action to develop teachers as researchers in the schools. Tikunoff and Ward have offered basic rules for collaborative research that have guided this Teachers as Researchers program.

Our program began with two all day orientation and research design planning sessions during the summer. Regular visits from the laboratory staff occurred throughout the academic year. At the end of the data collection phase of the teachers' research projects, some chose to request support from the collegiate staff in data analysis and in the writing of the final report. A guide for preparing qualititative or quantitative type papers was provided for each participant. Plans were then made to present their studies to either the teachers within their districts or at educational conferences.

Several problems have been identified by the project staff and participants. Recognition of these are important as precursors to the implementation of more productive projects in the future. Some of these problems are:

1. Communications. The time lag between activities, such as between the administration of surveys and the processing of summaries of the data, was frequently too long.
2. Data. There were too much data, from several schools, and they were not organized effectively for analysis.
3. Plans. These were not sufficiently firm before the rush that accompanied the beginning of the school year.
4. Statistics. The relationship between the size of attitude changes and their significance was difficult to explain.
5. Personal problems. Illness and extra school commitments were not anticipated.

In spite of problems, projects involving teachers as researchers are worthwhile. The most direct implication that we are able to discern from the Teachers as Researchers Project is that teachers want and need professional development opportunities. They will make sacrifices of time and energy order to find access to these programs when they are offered partnerships in research. This approach wherein the teacher researcher is creatively involved in the selection, design, implementation, analysis, and outcomes assessment of research programs is worthy of further development. We see this process as a practical way to move research into practice.

FACTORS INFLUENCING IMPLEMENTATION OF DESIRED OUTCOMES OF A SCIENCE INSTITUTE

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This study focused on factors that influenced implementation of desired outcomes of in-service institutes to prepare science teachers to serve as resources in their "backhome" districts. The study involved 19 institute participants--all middle/junior high school science teachers--who, upon their return to their home districts, were to assist out-of-field/out-of-date science teachers. Factors that were under investigation were the institute participants' sense of efficacy regarding his/her ability to perform various skills in the classroom and to teach others to perform those skills, prior leadership experience, professional socialization, number of years of science teaching experience, motivation for attending, knowledge of desired outcomes of the institute, undergraduate major and/or minor, and institutional/administrative support. Data were gathered through pre-, post-, and follow-up questionnaires and

through interviews with participants and their principals. They were then analyzed both quantitatively and qualitatively. Among the factors found to have significant effect on implementation of the desired outcomes were institutional/administrative support to plan and carry out teacher training, both intrinsic and extrinsic motivation of the participant for attending the institute, the participant's prior experience conducting workshops, and the teacher's sense of efficacy regarding his/her ability to coach other teachers.

COOPERATIVE LEARNING AND GROUP EDUCATIONAL MODULES: EFFECTS ON COGNITIVE ACHIEVEMENT OF HIGH SCHOOL BIOLOGY STUDENTS

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The purpose of this study was to examine the effects of the Group Educational Modules (GEM) materials and cooperative learning techniques on the achievement of high school biology students. GEM materials are self-instructional packets designed for use with groups of high school biology students. Cooperative learning is a classroom learning environment in which students work in small, mixed ability groups toward a common goal and are rewarded for doing well as a group.

A 2 x 2 factorial design was used in this study. The independent variables considered included: (1) participation of students in the GEM project, and (2) use of cooperative learning techniques including heterogeneous grouping and group incentives. The dependent variable for all treatment groups were scores on the instrument developed for this study.

Eleven teachers with 36 classes and 715 students were included in this study. All teachers involved covered the same general subject matter during the study period. An analysis of co-variance (ANCOVA) was used as the data analysis procedure. Significant differences were found in the achievement of students using GEM materials and those using traditional instructional approaches. The use of cooperative learning produced significant differences when compared to traditional classroom structures.

The results of this study indicate that allowing students to work together in groups, whether heterogeneous or not, may be one of the reasons for the success of both the GEM materials and cooperative learning. The implication is that there is an additive effect in using the components of cooperative learning. Heterogeneous grouping and group incentives appear necessary to maximize achievement.

TEACHING/LEARNING STYLES, PERFORMANCE, AND STUDENTS' TEACHING EVALUATION IN S/T/E/S-FOCUSED SCIENCE TEACHER EDUCATION A QUASI-QUANTITATIVE PROBE OF A CASE STUDY

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In response to the new needs for Science/Technology/Environment/Society (S/T/E/S) literate science teachers, a S/T/E/S-oriented Integrated Subject Matter/Methods Course - Individualized Eclectic Examination (ISMMC-IEE) combination model of instruction was implemented in three courses within college science teacher training program. These courses served as case studies for class-based, quasi-quantitative pilot investigation aimed at gaining a deeper insight into some of the issues involved in the implementation in college of non-traditional, open-ended, problem-solving/decision-making-oriented teaching strategies which are in dissonance with the cognitive/affective styles and 'functional paradigms' of most students.

This probe into the 'dissonance issue' revealed that prospective teachers are capable of handling the new instructional model and do gain in their higher-level cognitive performance (HLCP). Their achievements on 'traditional'/conventional-type assignments were different from those on the IEEs-type assignments. However, undergraduates perceive these courses to be either difficult or not in accord with their 'acquiring knowledge' needs. The less advanced in their training program and experienced in teaching the students were, the higher the level of difficulty of the higher-level cognitive learning-oriented ISMMC-IEE combination was perceived by them. Regardless of the extent of the students' appreciation of the teaching style, they were appreciative of what they perceived to be the (overall positive) courses outcomes. However, the highly positive appreciation of the instructional techniques and teaching style by graduates is not shared by the undergraduate students.

The current study suggests that although the ISMMC-IEE model is useful in S/T/E/S-oriented courses in science teacher training programs, a special attention to the implementation stage is required to close the gap between students' and S/T/E/S educators' functional paradigms. The benefits of the proposed model in terms of students' S/T/E/S literacy outweigh by far the trade offs in terms of students' appreciation of the teaching style/strategies employed.

STAR: SCIENCE TEACHING ACTION RESEARCH IN THE ELEMENTARY SCHOOL

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The STAR Project attempts to respond to the need for increased focus on science and technology in the elementary school grades and to utilize as much as possible existing instructional materials. The project consists of three phases. Phase I (86-87) involved gathering data about children learning of science process skills. These data were collected by researchers through written and practical activities and by making observations of individual children during regular science activities. Three instruments were utilized in the data collection over the period of the school year.

During Phase II (87-88) of the project the same classroom data were collected. In addition, each teacher used the data gathered in Phase I to define effective practice and to begin working toward improving his/her own teaching. Phase III (implementation, 88-89) of the project utilizes the "train the trainer" model. The STAR teachers participating in the research phase will receive training on how to use the results of the research to identify effective practices for their colleagues.

The written assessment provided detailed information on children's performance in each class, and was a valuable source of feedback for the teachers. The Science Process Observation Checklist (S.P.O.C.) results raised some interesting issues concerning the degree of teacher involvement, and the frequency of pupil involvement in an activity. Those activities which were observed to occur very infrequently were often associated with a high degree of teacher involvement. How important a factor is this teacher involvement? Could teacher involvement be differently, and perhaps more effectively, allocated? The practical test results provide an interesting comparison with the written assessment material. What is the precise nature of the relationship? How are we to interpret the differences in performance? Performance on some skills seemed linked with achievement band; other times the link seemed more tenuous. How is this to be interpreted?

These and other questions raised by the extensive data collected over the initial two years of the project will be presented and discussed.

TEACHERS' PERCEPTIONS OF BARRIERS IN UTILIZING SCIS-II

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While research results indicate that SCIS is much more effective than traditional approaches to teaching elementary science, in terms of student performance on achievement and process skill measures, it holds a modest percentage of the elementary science market. Further, many teachers do not share the positive view held by SCIS students about the program. In order to assist SCIS users and revisors, a study was undertaken to identify teachers' perceptions of barriers to the implementation of SCIS-II.

Data for the study were obtained from a two-part opinionaire. The first part was administered to individual elementary teachers in a metropolitan school district with 31 elementary schools. Part one included 41 questions which utilized a Likert-type scale to obtain teachers' perceptions of major barriers to the implementation of SCIS-II generally. The second part of the opinionaire was completed in the same district by groups of teachers at each grade level. Part two requested the identification of problems encountered in each section of each unit and of needed changes. Of the 685 elementary teachers in the district, 663, or 96.8%, completed part one. The number of grade level groups of teachers completing part two ranged from a low of 24 to a high of 30, for a return rate range of 77-97%.

Results from part one of the opinionaire include the following:

1. K-2 teachers rated the program more positively than did grade 3-6 teachers;
2. Teachers who rated the program highly perceived fewer barriers to effectively utilizing the program;
3. Teachers rated the program higher for developing social skills and a positive attitude than for teaching science content and process skills.

Results on part two of the opinionaire served to identify many problems unique to particular units, as well as problems shared by several units. In the latter category, the responding groups of teachers reported problems related to the viability and performance of the living organisms in all six of the life science units. And, all groups requested supplementary materials to be used when the living systems show little change from one class period to the next, when the living organisms die prematurely, and when more stimulating and challenging materials are judged to be needed. The small number of evaluative comments received for the last one third to one half of some units, and lack of insight shown through those comments, suggest a significant portion of teachers are quitting the units early.

Investigative elementary science will never be hassle-free, and work with living organisms over an extended period will continue to include a special set of problems. However, the next generation of SCIS revisions, if any, should be designated to be much more "user friendly." Further, developers of a new generation of elementary science instructional materials must design out many of the barriers perceived by teachers of SCIS, while retaining the impressive performance of students in SCIS.

AN EVALUATION OF A TEACHER ENHANCEMENT PROJECT ON EDUCATIONAL COMPUTING

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The Biological Sciences Curriculum Study
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The Biological Sciences Curriculum Study (BSCS) with support from the National Science Foundation (NSF), Colorado Springs Public School District 11, Pikes Peak Board of Cooperative Services, and software publishers is conducting a three-year project (ENLIST Micros II) to develop a model for implementing educational computing in school science. ENLIST Micros II has as its primary goal to develop and test a model for implementing educational computing in science courses. This paper is a report of the evaluation of the second year of the project.

During the second year of the project, project staff conducted one two-day workshop and four seminars for 22 lead teachers who were to be group leaders, and five two-day workshops and four seminars for 80 teachers who were new participants in the project. Throughout the year the project staff, group leaders, and new participants worked together to improve the use of microcomputers in science teaching.

Project staff gathered descriptive data on background characteristics, prior experience with microcomputers, and educational level of the leaders and new participants. Leaders and new participants evaluated the workshops and seminars using questionnaires. The project used the Concerns Based Adoption Model (CBAM) developed by the Research and Development Center for Teacher Education at University of Texas as the approach to evaluating implementation. Leaders and new participants completed the Stages of Concern Questionnaire and the Microcomputer Use in Science Teaching checklist as pretests and posttests to indicate their concerns about and degree of implementing microcomputers in science teaching.

The leaders and new participants were experienced teachers with the majority having masters degrees. Most of the leaders had used microcomputers in science teaching prior to the project; more than three fourths of the new participants, however, were non-users or novices in educational computing. The leaders and new participants gave the workshops and seminars high ratings. By the end of the second year 100 percent of

the leaders and 84.6 percent of the new participants were using microcomputers to manage instruction and 92.3 percent of the leaders and 66.7 percent of the new participants indicated that their students were using microcomputers to learn science. The profiles of the leaders and new participants on the Stages of Concern Questionnaire changed from one typical of non-users toward one appropriate for users of an innovation.

PROPOSALS FOR SUSTAINING STUDENTS' INTEREST IN SCIENCE AND TECHNOLOGY IN A NON-WESTERN CULTURE

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The radical shift in curriculum development in science with its attendant changes in instructional methodologies which became a world wide phenomenon in the 60's was well received also in the developing Non-western cultures.

While the characteristics of this new shift have been used to reform science education in Nigeria, it would seem that the socio-cultural milieu in which they are operated have been neglected to a certain extent.

Believing that interest could be sustained through (1) emphasizing points on which school science and cultural common sense converge and (2) de-emphasizing area of divergence, it is feasible to fashion out an indigenous curriculum and instruction model rooted in our eco-cultural environment.

This paper attempts to address this issue by outlining the main ingredients for the development of such a curriculum and instruction model.

A CROSS-CULTURAL STUDY OF HIGH SCHOOL BIOLOGY CLASSROOMS: TEACHERS AND STUDENT TEACHERS IN PANAMA AND THE U.S.

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Recent proposals for improving teacher education call for increased duration and intensity of interaction among practicing teachers, teacher educators, and student teachers. Currently, student teaching is the key element for this interaction. In spite of its importance in the education of secondary science teachers, student teaching has received little attention from science education research.

This study examines the interactions that occur among student teachers, experienced high school biology teachers, and university faculty in two high schools, one in Panama and one in the U.S. Observations of classes taught by student teachers and by experienced teachers constitute part of the data. Interviews with students, teachers, student teachers, and university faculty who represent the student teachers, as well as artifacts of teaching (tests, laboratory guide sheets, etc.) complete the data set.

Findings suggest that student teachers adopt the practical orientation of experienced teachers pertaining to classroom management and control, lesson content, and laboratory work. Experienced high school biology teachers had a strong impact on student teachers' actions and beliefs, especially regarding the role of the high school biology teacher and the teaching-learning process. Casual conversation and close personal interaction on a daily basis over 10 weeks appear to influence practices and beliefs to an important extent whereas university courses in teaching are perceived as lacking contact with reality of the work of teaching high school biology. These findings suggest that placement of student teachers should be based on careful appraisal of experienced teachers' practices and beliefs about teaching and learning.

TEACHING INVESTIGATIVE SKILLS THROUGH COMPUTER SIMULATION

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There appears to be a great deal of research suggesting that using microcomputer simulation as an instructional method is as effective as usual methods, particularly in the skills area. However, several advantages of using computer simulations suggest otherwise. This study was undertaken to find if investigative skills could be taught through a computer simulation. The investigative skills used in this study were identifying variables both dependent and independent, manipulating variables, and controlling variables. It is the first phase of a larger study dealing with a range of investigative skills. The population selected for the study consisted of preservice elementary school teachers; one third of the sample were seniors while two-thirds were in their junior year. All participating teachers were female. They had been admitted to the teacher preparation program of a major university. Intact classes were used. Three treatment groups were selected. One group (N = 21) was the simulation group; this group was instructed in investigative skills through the use of a computer simulation of an investigation. Another group (N = 17) was instructed through a lecture demonstration of an investigation; this group was designated as the dry laboratory group (dry lab). The third group (N = 19) was taught investigative skills through conducting an investigation in the laboratory; this was designated as the wet lab group. The investigation was the same for all groups.

The research design used in the study was posttest only. The total number of preservice teachers was 57. All subjects were female and had entered a teacher preparation program.

Treatments consisted of designing a computer simulation illustrating an investigation and emphasizing the selected investigative skills. From the simulation a script was developed for the lecture; the script contained the same information as on the simulation. The same script was used to design a laboratory investigation.

A paper and pencil test was used to measure the preservice teachers' ability to identify variables, manipulate variables, and control variables, and contained items on identifying, manipulation, and controlling variables. The test was twenty points. The treatments were administered to the groups at the same time. All groups were given the same length of time for treatment; they could review the computer simulation, discuss any aspect of the investigation presented through lecture demonstration or conduct any activity of the laboratory investigation. One week following the treatment a posttest was administered to each group. Scores of the participating teachers were analyzed to identify any differences evident among the groups.

An analysis of scores indicated that there was no difference among the groups in identifying variables. There was no difference between the score of the simulation group and the dry lab group. A significant difference was indicated, however, between both the simulation group, dry lab group and wet lab group; the mean scores for the simulation group were higher. These differences were noted on manipulating variable and controlling variable.

The results seem to indicate that computer simulation is an effective method for teaching investigative skills. However, the dry laboratory method was nearly equally effective. Both computer simulation and dry laboratory methods are essentially passive while the laboratory method stressed student activity. A disruption factor may be operating in the laboratory method where teachers were manipulating equipment. This factor may be lacking in the dry lab method and computer simulation methods; teachers were able to concentrate on the information being presented rather than dividing their attention between the presentation of information and manipulation of equipment.

The study also emphasized several problems related to the use of computer simulation to teach investigative skills. These problems may have profound effects in current science instruction.

NEUROCOGNITIVE ACTIVITY OF HIGH SCHOOL FEMALE AND MALE STUDENTS DURING PROBLEM SOLVING TASKS IN CHEMISTRY

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Solving problems in high school chemistry has been a student difficulty which has frustrated the students and their chemistry teachers for many years. A common conclusion is that the student difficulties are related primarily to limitations in cognitive abilities of memory and reasoning. Most of the research studies reported have investigated the problem solving ability of high school chemistry students through the use of indirect methods of assessment incorporating standard pencil and paper problem tests to show the results of their work. In a few studies students were asked to describe orally the process they used to solve chemistry problems. Considerable evidence suggests that gender differences in cognitive functioning do exist in learning science content and processes.

The major purpose of this study was to examine the brain activity (images) of high school students while they were engaged in problem-solving tasks. No studies have been reported where a non-invasive topographic brain mapping system has been used to investigate neurocognitive patterns of individual students while they are solving chemistry problems.

Female and male chemistry students were individually examined using the Brain Atlas III (BAIII) topographic brain mapping system. They were given memory, reasoning and spatial relations tasks related to high school chemistry. Brain electrical activity was collected from twenty electrodes attached to the subject's head by means of a nylon cap. Electrical activity from each scalp location was amplified and stored in raw EEG data files. Values were converted to integrated brain maps using a 16 color scale.

During the memory task, raw EEG was collected while the subject listened to the name of an element from the tape and then orally gave the chemical symbol for the element into a microphone. This was followed by an oral expression of correctness; High or Low. The voice responses produced electrical pulse markers on the O2 channel of the raw EEG record. Mathematical proportions were used for the reasoning task.

Analysis of the female and male student responses for the elements, mathematics analogies and spatial relations tasks showed different brain map patterns, and different waveform patterns at each of the different scalp sites. A series of colored 2x2 slides showing colored brain maps and waveform patterns taken from the computer monitor will be presented. Colored slides showing results of statistical analyses will also be presented.

This investigation represents a new approach to the study of learning difficulties in science instruction, and provides new insights into brain functions of adolescent students. It is anticipated that further study will lead to the use of student brain electrical activity results to assist teachers in planning science instruction, and to promote student self-confidence and positive attitude toward learning science.

THE EFFECT OF NEW VOCABULARY ON PROBLEM SOLVING IN NOVICE PHYSICS STUDENTS

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One of the difficulties encountered by novice problem solvers in introductory physics is in the area of problem solving. It has been shown in other studies that poor problem solvers are affected by the surface aspects of the problem in contrast with more efficient problem solvers who are capable of constructing a mental model of the physical situation before the mechanics to solve the problem are begun. It is hypothesized that a neophyte physics problem solver focuses on the technical terminology of physics rather than on the underlining process; the new vocabulary that is introduced confounds the process of problem solving. The treatment in the experimental study will be a two-hour computer-aided tutorial introducing the subjects to concepts in electromagnetism along with examples in solving electromagnetic problems. Two treatments are being developed which are identical except in the inclusion or exclusion of technical terms (T or NT). A population of 50 high school students ages 15 to 18 will be randomly assigned to four groups. Two groups will receive either the T or NT treatment before electromagnetism is introduced in the classroom and two groups will receive the treatments after electromagnetism is covered in the classroom. All four groups will receive the same paper and pencil test after the treatment to measure achievement. It is conjectured that the classroom pre-instruction group will show more of a difference between the T and NT groups and that in the classroom pre-instruction group the NT group will have a higher score on the paper and pencil test.

SHORT-TERM MEMORY LIMITATIONS AND PROBLEM SOLVING

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In order to arrive at the solution of a word problem, a number of mental operations must be executed. First, the text has to be read and encoded into a mental representation which is stored in short-term memory (STM). Consequently, task relevant schemata have to be searched and activated in long term memory (LTM). Finally, the activated schemata have to be retrieved and brought into short-term memory to be assembled and executed by the central executive. Problem solving performance, thus, becomes a function of the amount and quality of the schemata available LTM and of the capacity of the STM to handle the amount of data and the type of processes involved. Previous research has shown that short-term memory highly correlates with performance on complex problems in physical science.

This study investigated the impact of computer generated homework on problem solving performance. The treatment consisted of four computer programs characterized by the number of arithmetical manipulations necessary to arrive at the correct solution. This number is thought to be some linear function of a problem's short-term storage demand.

Thirty-one college students enrolled in Physical Science I, a course for non-science majors, participated in this study. The ratio span was used to estimate the subjects' short-term storage resources, and with it their membership to one of the short-term storage groups: STSS 1, STSS 2, or STSS 3. Within each group, half of the subjects were randomly assigned to either the treatment or the control group, the latter consisting of homework problems in the traditional paper & pencil format.

The results of this study show that the treatment group scored significantly higher on the post-test than the control group. At the same time, while there existed significant correlations between performance and STSS in the control group; they did not exist in the treatment group. The results also indicated that the students in the computer group had a better grasp of the concepts related to the topic.

TEACHERS' PROBLEM SOLVING STRATEGIES: THE CASE OF HIGH SCHOOL PHYSICS TEACHERS COMMITTED TO TEACHING FOR CONCEPTUAL CHANGE

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The purpose of this study was to investigate the cognitive strategies that high school physics teachers use to solve their own pedagogical problems when they teach for conceptual change. In the field of science education many international efforts have been devoted to the identification and modification of students' conceptions of natural phenomena. However, very little is known about the way teachers solve the problems they encounter when they develop conceptual change teaching strategies. The questions dealt with in this study aimed at uncovering the complexity of the problem-solving processes of high school physics teachers who teach for conceptual change. It was hypothesized that two types of inquiry processes would be involved: inquiry into the problem and inquiry into the solution.

This investigation is a case study of two high school physics teachers who weekly reflected on self-selected problems. A model of the cognitive strategies used by the participant teachers was developed from the analysis and interpretation of the conversation transcripts.

Accountable teachers are those who can give credit and rationale to their actions and who are able to formulate and solve their own professional problems. In other words, accountable teachers need to be natural inquirers. Understanding the science teachers' processes of solving problems will help scienc educators to improve the quality of their interactions with preservice teachers and professional teachers in two ways: science educators will be better able to educate life-long inquirers and to imprint a dynamics of permanent change in schools.

INFLUENCE OF TASK CONTEXT ON PROPORTIONAL PROBLEM SOLVING

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Proportional problem solving has been studied for several decades. Its importance has been long acknowledged in that problems abound in the physical sciences and the consumer world.

Piaget and Inhelder (1958) used various tasks of geometric and physical phenomena to study proportional reasoning as an element of formal operational thought. During the decade of 1960 and the decade of 1970 several studies supported the Piagetian view. Many of these studies

employed a wide range of various tasks. Strategies and success rates seemed to vary among types of tasks presented to subjects over a wide range of ages, suggesting the influences of task context on problem solving.

By 1980 researchers seemed less concerned with the association of the intellectual level and the successfulness on proportional reasoning and were approaching the topic from an information processing point of view.

The proposed study will investigate the effect of task content upon strategies used by students in solving problems of proportionality. It is conjectured that a qualitative period of analysis precedes a quantitative plan when the task is comprehensible to the subject.

Using two tasks contexts, one geometric and one physical phenomena, six tasks were structured mathematically as follows; two of addition structure, two of proportional structure, and two a combination of proportional and additional structure, each structure closely matched within each context.

TRANSLATION OF ALGEBRAIC EQUATIONS AND ITS RELATION TO FORMAL OPERATIONAL REASONING

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A large proportion of college students majoring in science are unable to translate even simple sentences into algebraic equations. Given the following sentence: There are six times as many students (S) as professors (P) at this university, most students write the following equation: $6S = P$, referred to as the Reversal error. It is plausible to suggest that in order to overcome the reversal error students need to operate in a hypothetico-deductive manner, i.e., performing a hypothetical operation which makes the group of professors six times larger than it really is ($S = 6P$). The objective of this study is to investigate the relation between student ability to translate sentences into equations, equations into sentences, and student performance in the following variables: formal operational reasoning, proportional reasoning and achievement in an introductory freshman level Chemistry I course. The results obtained show that: a) as the student ability to translate sentences into equations and equations into sentences (i.e., Total Score) increases, their mean scores in Chemistry I, Formal operational and Proportional reasoning increase; b) significant correlation between the Total score and Formal ($r = 0.51$; $p < 0.05$) and Proportional reasoning ($r = 0.57$; $p < 0.05$); c) ability to translate sentences into equations does not correlate with student scores in Chemistry I; d) ability to translate an equation into a sentence does correlate with student scores in Chemistry I. Finally, this study has found support for the hypothesis that students who lack formal operational reasoning (hypothetico-deductive reasoning) may experience more problems in the translation of algebraic equations.

CHANGES IN SECONDARY STUDENTS' REACTIONS TO THE CHERNOBYL NUCLEAR ACCIDENT FROM 1986 TO 1988

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Secondary school students were tested to assess their attitudes toward nuclear power plants before and after the accident at Chernobyl. Changes in attitude were analyzed with respect to the students' tendency to blame the accident on human error or the technology. Students' attitudes were assessed over two years after the accident to determine what they know and remember about the accident and whether any additional attitude changes have occurred.

The Attitude Scale of Nuclear Energy Assessment Battery was used as the measure of students' attitudes. A total of over 150 students participated in the study.

An analysis of variance for repeated measures was used to analyze the data. Pearson product-moment correlation coefficients were computed to look for relationships among the variables.

Results indicated that students' attitudes changed significantly as a result of the accident. These attitude changes were explained by applying the Theory of Reasoned Action. By 1988, there were no significant differences between secondary school students' attitudes prior to Chernobyl and either secondary school students in 1988 or those who were in the 16-17 year-old cohort in 1986.

USING THE PAST TO PREDICT THE FUTURE OF BIOEDUCATION: A CONTENT ANALYSIS OF THE AMERICAN BIOLOGY TEACHER

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The purpose of this study was to develop a conceptual framework for the messages about the future of biology teaching, both implicit and explicit, embodied in The American Biology Teacher, the most prominent journal of bioeducation in the U.S.A. Based on the aforementioned conceptual framework, a reliable analysis instrument was prepared. The instrument was then used to analyze selected articles in The American Biology Teacher which were identified as forecasting the future of bioeducation.

Major assumptions of this study were: (1) content analysis is a research method appropriate for revealing the manifest and latent content of selected articles in The American Biology Teacher journal; (2) analysis of past expressions of expectations for the future of biology teaching may help science educators do a better job of forecasting trends in bioeducation; (3) analysis of inaccurate past forecasts about the future of bioeducation may yield important principles which could be used to improve the accuracy of forecasting trends in science education.

Despite biology educators' penchant for forecasting the future of bioeducation during the first 50 years (1938-1988) in which The American Biology Teacher has been published, content analysis revealed that unforeseen cultural forces, technological developments, and international situations can alter bioeducation's predicted course quite dramatically. Evidence was gathered to demonstrate that a bioeducator's forecast can be self-fulfilling, self-negating, or independent of the event being forecast. Suggestions are offered to help science educators avoid some of the forecasting pitfalls of the past and to identify potentially reliable sources of information from which more accurate forecasts of trends in bioeducation can be derived. If it is true that "No one can walk backward into the future" (Joseph Hergesheimer, American writer, 1917), perhaps an occasional rearward glance can help science educators insure their forward progress.

THE IMPACT OF EDUCATIONAL REFORM ON THE DEVELOPMENT OF SCIENCE OBJECTIVES

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The purpose of this study was to analyze the impact of the school reform movement and the resulting efforts by some school districts reorganizing science curricula. Data collected about the type and cognitive level of science objectives written as part of the Illinois Learning Assessment Plan were collected from a variety of school districts including rural, suburban, large, small, unit districts, and high school districts with feeder school systems. Science objectives written by committees of teachers were entered into a computer database and sorted according to grade level, type of science goal addressed, and level of Bloom's cognitive taxonomy. The grade levels addressed are third, sixth, eighth and eleventh.

A total of 486 objectives were written by the five districts. Of the 486 objectives, 331 or 68% were written at the knowledge and comprehension levels and 32% at the upper levels of Bloom's taxonomy. More than two objectives were written at the low levels for every one written at the upper levels. At the high school level 61% of the objectives were written at the lower levels, while at the elementary level 70% were written at the lower levels.

An examination of the elementary grade level objectives revealed some interesting data. At grade 8, 24.7% of the objectives addressed the upper levels of Bloom's taxonomy. At grade 6, 31% of the objectives addressed the upper levels while at grade 3, the number was 24.7%. It is interesting to note that grade 6 had the highest percentage of objectives at the upper levels of the taxonomy while grades 8 and 3 were equal. This was unexpected. The expectation was that the percentage of upper level objectives would increase as the grade level and the developmental level of the student increased.

THE CONSTRUCTION OF SCHOOL PHYSICS KNOWLEDGE: AN ETHNOGRAPHIC STUDY OF THREE EXPERIENCED HIGH SCHOOL TEACHERS

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Recently there has been a major concern among educational researchers about the nature of how teachers actually organize subject matter as they strive to communicate the academic content embedded in the school curriculum. This study was designed to learn about how physics teachers actually construct subject matter in their daily interaction with students and curriculum materials. For this purpose three experienced high school physics teachers were observed during six consecutive months. Information about subject matter was gathered through several ethnographic techniques including: fieldnotes, videotapes, documents and interviews. More than 200 observations were conducted in conjunction with 25 videotapes of live-classes and countless formal and informal interviews with teachers. The research was conducted at three different high schools located in the midwest and where physics is an elective.

For analytical purposes, this paper focuses on how the participant teachers enacted the unit on dynamics by sequentially organizing the different topics that form that theme. In this sense, the study tries to answer the following question: What is the nature of the coherence in the information content delivered by teachers as they enacted the theme on dynamics? In order to shed light on the above question, the researcher conducted a discourse analysis of the different lessons that comprised the teaching of the theme on dynamics for each individual teacher.

Analysis of the data, in the context of a constructivist framework, reveals that the teachers in their daily interaction with students and curriculum material constructed different structures of subject matter for a similar instructional unit by breaking the units into topics which may or may not be logically connected. The teachers enacted different sets of information when organizing the various topics that constituted an instructional unit on dynamics. This difference varied according to the nature of the information content delivered in each topic, the logical connections between these topics, and the physical materials used to deliver them.

The findings of this study have implications for student learning, staff development, and further research in science teaching. First of all, it can be observed that similar groups of high school students are being delivered differently organized bodies of knowledge for similar instructional units. This raises the question: What knowledge are students themselves actually constructing and how does it differ among them? Secondly, the study presents three case studies of high school physics teaching. Empirical information of this nature can be useful both in the process of informing prospective physics teachers about how experienced teachers deal with a theme in real life and in the need of having participant teachers themselves reflect upon their own practice as a mechanism to enhance the teaching profession. Third, the study describes a methodology to study the coherence of the teachers' discourse as subject matter is enacted. This methodology and its inherent metalanguage can be used to learn about subject matter enactment either within a whole school discipline or among different disciplines of the school science curriculum.

NEW DOCTORAL PROGRAMS IN SCIENCE AND MATHEMATICS EDUCATION: FROM CONCEPTION TO DECLARATIVE AND PROCEDURAL DECISIONS

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Current concerns about the state of American education, as well as potential sources for solutions of a declarative and a procedural nature, provided the focus and rationale for new doctoral programs in science education and mathematics education.

New doctoral programs in science education and mathematics education whose conceptual framework was organized around an existing college of education which emphasized curriculum, technology and an emerging emphasis on cognition, as well as an existing college of pure and applied science, will be discussed. Furthermore, the conceptual framework incorporates three developmental issues which have emerged from science and mathematics educational research during the last 25 years. First, the importance of new doctoral graduates in leadership roles for primary and secondary education was considered. Second, the importance of responding to the acute need for science and mathematics teacher training was considered. Third, the importance of responding to the rapid growth and new mission of community colleges which emerged in the 1970s was considered.

A final aspect of program development was articulation of declarative and procedural decisions. Central to those decisions are curriculum development, inter-college cooperation within an existing university structure, development of a center structure for purposes of research specialization and of extramural funding, as well as recruitment of doctoral students. Since programs are dynamic in nature, discussion will also extrapolate beyond current parameters of programs.

AN EMPIRICAL INVESTIGATION INTO FACTORS AFFECTING ACHIEVEMENT IN HIGH-SCHOOL PHYSICS

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The study aimed at determining the relative importance of selected factors on the achievement of males and females (taken as separate groups) in physics. A sample consisting of 358 eleventh grade science-stream students (males = 159, females = 199) responded to six instruments.

The data analysis revealed statistically significant differences between males and females on the following variables: achievement in physics, attitudes toward physics, and mathematical skills ability. The differences were in favor of females on attitudes toward physics and in favor of males on the other two variables. Statistically nonsignificant differences were found between the above two groups on self-concept of achievement in physics and on level of comprehension of prerequisite physics concepts.

The stepwise multiple regression for the prediction of achievement in physics of the above two groups revealed that three variables entered the regression equation in each one of them. In the case of males, the variables (ordered by step) were: cognitive development, self-concept, and mathematical skills ability. Whereas the variables entering the equation (again ordered by step) in the case of females were: mathematical skills ability, self-concept, and level of comprehension of prerequisite physics concepts.

BUILDING AN ORGANIZED KNOWLEDGE BASE: CONCEPT MAPPING AND ACHIEVEMENT IN SECONDARY SCHOOL PHYSICS

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Direct teaching of problem solving methods to high school physics students met with little success. Expert problem solving depended upon an organized knowledge base. Concept mapping was found to be a key to organizing an effective knowledge base. The investigation of the effect of the degree of concept mapping on achievement was the purpose of this study.

Six intact high school physics classes, taught by this investigator, took part in the study. Two classes were control groups and received standard instruction. Four classes received six weeks of concept mapping instruction prior to the unit under study. Two of these four classes were the low level treatment group and were required to submit concept maps at the conclusion of the instruction. The other two classes were the high level treatment group and were required to submit concept maps at the beginning and at the conclusion of the unit under study. One class from each treatment group took a pretest prior to instruction.

An analysis of the posttest results revealed no pretest sensitization. A one-way analysis of covariance indicated a significant main effect at the $p < .05$ level. A pair of single-df comparisons of the adjusted treatment means resulted in significant differences ($p < .05$) between the control group and the average of the treatment means as well as between the two experimental groups.

It can be concluded that for this sample (upper middle class high school physics students), mapping concepts prior to, during, and subsequent to instruction led to greater achievement as measured by posttest scores.

TOWARD THE DEVELOPMENT OF AN ELEMENTARY TEACHERS' SCIENCE TEACHING EFFICACY BELIEF INSTRUMENT

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The purpose of this study was to develop and validate an instrument entitled the Science Teaching Efficacy Belief Instrument (STEBI), that would allow researchers to analyze efficacy beliefs of elementary teachers with regard to science teaching. Primary attention was given to the specification and inclusion of teacher behaviors and demographic characteristics that correlated highly with general teacher efficacy beliefs. The present study involved instrument development, instrument refinement through a try-out study, and instrument reliability estimation and validation.

Scales were developed to measure Bandura's two theoretical constructs of efficacy beliefs and outcome expectancy beliefs in reference to elementary teachers' science teaching behaviors. Initial science-specific items were modeled after scales designed to measure these beliefs for teaching behaviors in general. These items were then subjected to content validity assessment by expert judges.

Continued development of the remaining items included item analysis, scale reliability assessment, and factor analysis of scale integrity. Using these procedures, items were statistically refined in a tryout study with seventy-one elementary teachers. These procedures were then repeated with the improved set of items in a major study with a final N or 308.

The two resulting subscales which combine to form the STEBI were named the Personal Science Teaching Outcome Expectancy scale. On the major sample, both scales performed with good reliability (Personal Science Teaching Efficacy Alpha=.92, Outcome Expectancy Alpha=.77) and factor analysis clearly demonstrated the distinctiveness of the constructs measured.

Finally, preliminary evidence of the construct validity of both scales was clearly demonstrated by their predictable covariance with variables such as teaching experience, motivation to teach science, self-evaluation of science teaching ability, subject preference, time spent teaching science, use of activity-based science instruction, and principal rating of teachers' science teaching effectiveness.

THE INFLUENCE OF A DIVERSIFIED INSTRUCTIONAL STRATEGY ON AN UNDERSTANDING OF THE NATURE OF SCIENTIFIC/EVOLUTIONARY THEORY

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The intent of this study was to investigate the influence of a diversified instructional strategy to overcome misconceptions held by freshmen undergraduate students with respect to the nature of a scientific theory. The theory of evolution was selected because it is the most significant unifying theme within the discipline of biology. Data were collected from two concurrent intact general biology classes, during a three-week summer session course when evolution was taught as a unit of study. Both classes were pretested for background knowledge of evolutionary biology concepts, attitude regarding evolution, and an understanding of the nature of science. Intact groups received instruction from independent biology faculty members, both of whom agreed to make use of the same course outline and sequential introduction of topics. The groups were selected on the basis of the instructors' willingness to participate in the study. The experimental group differed from the control along one dimension; after having been exposed to an introductory lecture on the unit of evolution, the investigator provided the experimental group with an opportunity to discuss their positions regarding the theory of evolution. Discussion groups were asked to resolve potential conflicts arising among themselves and present a consensus opinion. The investigator further provided an interactive lecture/discussion to resolve misconceptions arising as a result of the small group discussions. Both groups were posttested using the same measures administered on the pretest. Results indicated no significant differences existed between groups for pretest scores with respect to an understanding of evolutionary concepts, attitude toward evolution, or an understanding of the nature of science. The analysis of between group posttest scores revealed no significant differences for evolutionary concepts; however, with respect to an understanding of the nature of science/attitude toward evolution, a significant difference was found for the experimental group ($p < 0.05$). Therefore, although a traditional lecture approach provided an adequate basis for learning evolutionary concepts, attitude toward evolution and an understanding of the theoretical foundation upon which evolution is based, are more likely to change if sufficient opportunities are provided to allow students to resolve potential misconceptions that act as impediments to a more comprehensive understanding of scientific claims, constructed upon theoretical evidence, and possessing potential competing patterns of explanation.

MODIFICATION AND VALIDATION OF A TEST OF BASIC PROCESS SKILLS USING DIFFERENT METHODS OF TEST ADMINISTRATION

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The purpose of this study was to develop instruments that assess basic process skills and to validate a paper and pencil test of basic process skills (BAPS). Three test formats including paper and pencil, station, and interview were developed so that comparisons could be made between written tests and those using actual demonstration.

Test formats were designed to be parallel, with each test measuring basic process skills. All were designed to be administered in one class period or less, and contained content-free test items of varying difficulties addressing each process skill. Average readability for all formats was below the fourth grade level.

Instruments were piloted and revised before final administration. The paper and pencil test was piloted with 276 students in the 3rd through 7th grades. The station test was pilot tested with 27 students and the interview test was pilot tested with 15 students. Both of these groups were in the 4th through 6th grades.

After development and pilot testing, the effects of test format on basic process skill achievement were examined using the variables of gender, grade level, and cognitive ability. Final versions of the test formats were administered to 393 students in a rural elementary and middle school, which included grades 4 through 8. From this sample, 390 students were given the paper and pencil test, 113 students were given the station test, and 41 were given the interview test.

Analysis of variance procedures were used in interpreting the data. Results indicated that an effect due to test format was present, with students achieving significantly higher scores on the paper and pencil test ($p < .001$).

High correlations were found between the paper and pencil test format and the station and interview test formats. These high correlations indicate that the Test of Basic Process Skills (BAPS) is measuring the constructs it purports to measure.

HYPOTHETICO-DEDUCTIVE LOGIC, SCIENCE PROCESS SKILLS AND BIOLOGY LEARNING

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The aim of the study was to investigate learning difficulties in biology which might be associated with undeveloped hypothetico-deductive logic and lack of mastery of science process skills. To accomplish this aim, a learning unit in biology (structure and function of enzymes in the living systems) was taught to 202 ninth grade students from 5 different urban junior-high schools. Before the learning unit, which lasted for 6 weeks, began, students' mastery of inquiry skills and hypothetic-deductive logic was tested by written questionnaires. At the end of the learning, students' level of understanding of biological concepts was assessed by a 25 open-ended question test. Analysis of the level of the concepts which are introduced in this specific unit has found that at least 70% of the concepts can be considered as abstract and formal concepts, while only 14 percent of the students had the necessary skills to cope with those bio-molecular concepts.

Analysis of the relations among the variables revealed that the variables "control of variables" and "combinatorial analysis" (part of the hypothetico-deductive logic skills) and "interpretation of the experimental data" and "graph reading" (science process skills) were the best predictors of students' achievements in learning this topic. Further analysis found specific learning difficulties of students who did not use the hypothetico-deductive logic while exposed to learning of new scientific concepts.

AN ELECTRICITY UNIT:
PROVIDING LEARNING DISABLED STUDENTS OPPORTUNITIES FOR SUCCESS

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The Education for All Handicapped Children Act of 1975 (P.L.94-142) mandated that full and appropriate services be provided for all handicapped children within the least restrictive environment. This set the stage for mildly handicapped students to be integrated into the regular classroom and for teachers to have to deal with the wide range of abilities that this mainstreaming produced.

Science classes which are activity based appear to offer particularly important opportunities for mildly handicapped, especially Learning Disabled (LD), students. However, teachers report barriers to teaching science to handicapped students. These barriers include feeling unprepared and inadequate to teach science to students with special needs; taking time from other students to work with handicapped students; lack of supplies and equipment; inappropriate science programs in use; and lack of inservice training. These needs must be addressed to help teachers provide quality science for all students and opportunities for success for the LD student.

The purpose of this study was to determine whether an activity-centered electricity unit for intermediate grades developed for the local power company would be appropriate--that is, provide opportunities for success--for LD students. To achieve this purpose a specific examination of the unit as it was taught to a class of eight LD students was conducted to determine what modifications were needed in the unit itself and what strategies should be shared with teachers using the unit to provide successful experiences for LD students who typically have normal or above IQs but deficits in reading/language skills.

Procedures included preinstructional individual interviews to determine preconceptions, observations during instruction, post written assessments ("worksheets") and individual interviews. During instruction, the lessons as written were followed closely, but special attention was given to providing support to the students in their development of language skills, for example, helping them learn to distinguish terms and symbols important in the unit and to provide written and oral feedback.

Results were positive. The preinstructional interviews indicated that only a few students had, at best, some sketchy knowledge of some aspects of electricity (e.g. constructing simple circuits and safety) and none had knowledge of other more complex aspects (e.g. production and need for conservation of electricity). Class observation and post written and oral assessments showed that the students enjoyed and mastered skills which required the use of equipment, for example, putting together simple circuits. Development of concepts directly related to the concrete activities were also easily mastered. Vocabulary development and more complex concepts were mastered by all but the lowest student, but they generally required much repetition in instruction.

The unit appears to have excellent potential for motivating LD students and providing them with opportunities to succeed. The study is resulting in a number of suggestions, revisions, and additions to assist teachers in providing successful experiences for mildly handicapped LD students in self-contained special education and mainstreamed classrooms.

STUDENTS' PARADIGMS, SPONTANEOUS AND ACQUIRED

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Inhelder has suggested that development of scientific theories in students is similar to the way theories had been developed throughout the history of science in which misconceptions would be part of the learner's effort to become consciously aware of how things work. Further, it has been hypothesized that students' common sense, naive theories would be formed spontaneously, given the same common phenomena and less information. However, spontaneous possession of ideas like those formulated by scientists with sophisticated information after many years of work is not plausible. Since the curriculum is the essential cultural factor that shapes students' theory, this study investigated the historical foundation of the school curriculum, while comparing this organization with the historical evolution of the biochemical activity of the cell. Using this framework to guide inquiry, the specific question was: "How do the entry-level knowledge of students, textbook information and classroom instruction influence development and stabilizing of students' theories?

Comparisons were made between the textbook's conceptual organization and development of the topic of the biochemical activity of the cell in the history of science. This information became the background for studying students' understanding of this topic before, during, and after instruction. Twenty Jordanian high school girls were randomly assigned to treatment and control groups. All were pretested and posttested using an author-designed open-ended test instrument. The treatment group was given seven lessons on the topic based on the framework described before. The control group continued in regular sessions.

Results showed substantial differences in use of propositional and functional knowledge among students in both groups. Propositional knowledge of many students was similar to that of scientists in the second of five historical paradigms. Like scientists of the past, these students believed that carbon dioxide is used for plant breathing and that heat energy is composed of particles that can form the weight of the body.

The reason that students' ideas were not changed by instruction is that textbook discussion about the function of respiration and photosynthesis supported vitalistic thinking. In the textbook's presentation of Van Helmont's conclusion "the body of plants comes from water," the textbook does not make it clear to students that this conclusion had been modified since the seventeenth century. The same occurred in presenting the Priestly experiment. Students would understand that plants absorbed carbon dioxide, while animals release it as a kind of breathing in the same way as Priestly. As a result, students who entered with a vitalistic viewpoint could understand the textbook's conceptualization of the function of photosynthesis and respiration since it was congruent with their vitalistic thinking.

Understanding of contemporary theories is confounded by textbooks that mix today's paradigms with prior ones without showing the reasoning that underlay their evolution. Textbook writers must be certain that the content included is logically consistent, and addressed to a consistent paradigm. Historical data can be used to strengthen understanding of how contemporary theory evolved. Teaching science should take into consideration students' entry-level knowledge in other science fields, such as chemistry and physics.

INVESTIGATING THE GENERALIZABILITY OF THE FORWARD TRANSFER EFFECT OF INSERTED QUESTIONS FROM SCIENCE TEXTS TO SCIENCE FILMS

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The forward transfer effect typically occurs when students read a segment of text followed by a question related to the text. After answering the question the student reads a subsequent text, presumably while paying close attention to a particular kind of restricted category of information or a particular kind of processing style which is suggested by the previously answered questions. For example, if a series of questions following text segments repeatedly asks for formulas, students tend to focus attention on formulas presented in later segments of the same text. Such forward effects of questions influence the kind (examples: formulas, chemicals) or processing style (examples: verbatim, conceptual) of information learned by readers. This particular effect is predicted by the general selective attention hypothesis which states that student can be influenced in the way they focus their attention on learning materials. However, the forward transfer effect has not been much studied with media other than text. Hence our question: Can inserted questions produce a forward transfer effect in students viewing science films, such as ones produced by the National Geographic Society, presented using a videotape medium?

In this study we plan to insert questions at regular intervals throughout the film. After each interval the videotape will be stopped and the students given the opportunity to answer each question. Subjects will be randomly assigned to one of two treatment groups or randomly to one of two control groups. One treatment group will receive verbatim-style questions inserted into the film and the other will receive conceptual-style questions inserted into the same film. One control group will view the same film and the second control group will view a placebo film but neither control group will receive inserted questions. Within each of these four groups, two subgroups will be randomly formed, resulting in a total of eight subgroups.

After students view the films, two different achievement tests will be administered. One subgroup within each of the four main groups will receive verbatim-style test items while the other subgroup will receive conceptual-style test items.

Our hypotheses are: (1) the verbatim treatment group will outperform the conceptual treatment group on the verbatim achievement test items, (2) the conceptual treatment group will outperform the verbatim treatment group on conceptual achievement test items, and (3) both treatment groups will outperform both control groups, but to a greater extent, the placebo control group, on both types of achievement test items. In other words, the style of inserted question is hypothesized to interact with the style of achievement test items.

GO FOR WHAT YOU KNOW: USING SOCIO-LINGUISTIC ANALYSIS TO UNDERSTAND APPARENT OFF-TASK BEHAVIOR IN A BIOLOGY CLASSROOM

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The main purpose of this paper is that of a teaching tool. The paper attempts to show some of the dangers of using qualitative research methodology as a means of evaluating a teacher's performance. The purpose of qualitative research is to understand, not to sort. At first glance Mrs. Martin's lesson seems to ramble and be off-task. When her work is analyzed more closely the subtleties of her style shine through. While the main points of her lesson that come directly from the textbook are of a low cognitive level, her off-task or side sequence discourse is rich with higher order thinking skills and has an affective component lacking in her textbook talk.

The second part of the paper is an exploration of the usage of established socio-linguistic methods to more fully understand what is going on in one biology classroom. It cannot be stated too strongly that this teacher, if evaluated by a classroom observation checklist, would probably be evaluated as weak. This paper looks beyond the superficial and dissects the conversations and interactions of the teacher and the students to get a clearer picture of how the teacher makes sense of her teaching.

So, as a teaching tool, others can see that sometimes the apparently dull lessons are far more interesting and there is a real danger in making quick decisions about how good or bad a lesson is based on a first impression, or a contrived checklist of so called evaluative ethnography.

SCORING CONCEPT MAPS: A COMPARISON OF METHODS

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Cognitive structure can be broadly defined as the knowledge a student holds in long term memory plus the organization of that knowledge. It has been measured in a variety of ways, but concept mapping may be one of the most flexible in that it can be both quantitatively and qualitatively scored. Although concept maps have been scored using several techniques, no direct comparisons of these procedures have occurred. Thus, it was the purpose of the present study to make these comparisons in terms of the relationships between concept maps and achievement.

The study was conducted in two high school physics classes with 20 students for a 4-week unit on electricity. Students were given a 14-item short answer pretest and the American Association of Physics Teachers exam; ACT, PSAT, and SAT scores and exam and course grades were also collected. Concept mapping was introduced the day after the unit exam following Novak and Gowin's procedures. Eight concept map measures were inspected for correlational relationships with grades and achievement. Three showed no such relationships, but positive relationships with achievement were associated with the number of levels, the number of chunks, and the number of correct links. In addition, the number of incorrect links and the number of correct but unlabeled links were negatively related to achievement, indicating that students with lower achievement are reluctant or unable to supply linking words.

Although this study used concept mapping as an evaluation procedure, it seems reasonable to predict that student understanding might be improved if teachers insist that students focus on the linking words on the concept maps they construct in class. Since inservice work has shown that teachers are not likely to do so, this hypothesis should be evaluated.

A SHORT TREATMENT PROGRAM TO INCREASE COGNITIVE FUNCTIONING, CREATIVITY, AND SYNTHESIZING ABILITY

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A week-long pre-enrollment program for improving cognitive functioning, creativity, and synthesizing ability in community college health science students was developed. This work was planned to prepare nursing and other health science students to equip themselves as well as possible for their future diagnostic responsibilities so that they will be more successful both as students and as professionals.

Diagnosis includes a grasp of a large quantity of data which arises from disease, trauma, or degeneration. It is an interplay of what are considered right- and left-mode brain functions. Left-mode functions include linear analysis and verbal ability, and right-mode functions include visual and holistic thinking; both are necessary. Health professionals who write down all possible data but understand no relationships function poorly, as do those who diagnose intuitively, but cannot analyze their patients' conditions to verify their intuitions.

This program was presented to incoming health science students who had not yet studied human physiology nor begun clinical courses. Sessions were held at the Science Education Center for five full days. Twenty participants completed the program. The three-part course consisted of segments that addressed the program. The three-part course consisted of segments that addressed the left mode, the right mode, and integration of the two: the computer language LOGO. Performance was measured with the Arlin Test of Formal Reasoning (ATFR) and the Torrance Tests of Creativity Figural Forms A and B as pretests and posttests. Posttest scores on both the ATFR and the Torrance Creativity Index (overall score) increased significantly for the treatment group, but not the controls. Findings were significant at the .02 level or better. Also, most treatment subjects demonstrated unusual ability to synthesize on the Torrance posttest. Torrance examiners report that this multiple-figure finding occurs in 5% of the population; it was found in 80% of the treatment group.

Thus, participants demonstrated significant increases in cognitive functioning, creativity, and synthesizing ability.

ENHANCING LEARNING IN THE LIFE SCIENCE LABORATORY

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The contemporary science laboratory provides students with an opportunity to handle, manipulate and investigate aspects of the classroom presentations. Due to the open design of the laboratory, however, many students lose the purpose of the exercise and stray from the systematic procedures followed in the experimental design. For many students, therefore, the laboratory loses its relevance to the lesson.

This study was designed to address this problem. Ninety students enrolled in college level General Biology II served as the subjects. The entire population was randomly divided into four equal groups. A control group of twenty-four students followed the traditional scheme of two lectures, one laboratory, and one seminar each week. Similarly, the three remaining groups followed the routine with one slight, but significant, addition. A placebo group of twenty-two students was treated to a fifteen to twenty minute presentation on the historical significance of the experiment at the conclusion of their weekly lab. The remaining two groups utilized photographs in their studies in the biology lab. One of these experimental

groups (N=23) recorded the events of their weekly lab exercises on black and white film. These students, therefore, had a sequential record of the events that took place during their lab investigations. This record was then utilized by group members in preparing for seminars, writing lab reports, and studying for tests. The fourth group (N=21) did not record their own lab activities on film but were, instead, treated to a pictorial summary of the lab exercise at the conclusion of each session.

Student learning was evaluated throughout the semester with three laboratory examinations. These exams consisted of questions pertaining to the macroscopic and microscopic examination of tissues, organs and organisms; graph and chart interpretation; and the understanding of chemical or physiological events. All of the questions on these practical tests pertained to items examined during the regular laboratory sessions. This type of exam has been shown by research to be an effective way of measuring the learning gained from the laboratory investigations. Furthermore, the results from an exam of this nature can be effectively scrutinized statistically.

When the results of this study were examined, it was found that the learning of biological information, especially cognitive applicability, could be enhanced through the use of photography. Both of the experimental groups scored significantly better on the laboratory practical than did members in the non-experimental groups. The experimental students as a whole seemed to be able to grasp biological concepts, including all ramifications, better than the non-experimental students and achieved a higher academic average in the General Biology course at the end of the semester.

INFLUENCE OF PROCEDURAL COMPLEXITY ON CONTENT TALK DURING SMALL-GROUP WORK IN SCIENCE

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The purpose of this study was to examine the influence of the procedural complexity of an activity on students' talk about content and procedures during small-group work. Sixteen small-group activities of differing procedural complexity were observed in three high school science classes. The procedural complexity of the activities was derived from the sum of ratings on five dimensions: 1) number of steps; 2) number and variety of materials; 3) difficulty or complexity of working with materials; 4) students' familiarity with materials, routines, procedures; and 5) requirement for social interaction. During group-work, instances of procedural talk and lower- and higher-level content talk among group members were recorded every five minutes. These data for each activity reflect proportions of five-minute segments during which each behavior occurred. Chi-square analysis indicated no relationship between proportion of procedural talk and procedural complexity or proportion of content talk and procedural complexity. However, there was a relationship between

procedural complexity and the difference in the proportions of procedural and content talk. Procedural talk occurred more than content talk when tasks were more procedurally complex.

A SURVEY INSTRUMENT FOR QUALITATIVE AND QUANTITATIVE EXAMINATION OF "HANDS-ON-SCIENCE" INSTRUCTION USING VIDEOTAPE-JURY REVIEW TECHNIQUES

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Hands-on-science teaching methods rank among the top research interests of elementary science teachers. This report describes a teacher-enhancement program designed to provide instruction for sixteen elementary teachers on the use of concrete manipulatives in classroom science teaching, with emphasis on the development and administration of an instrument to measure the extent to which the teachers made a transition toward the use of that mode of instruction in their classrooms. For this study, each teacher was required to teach four science lessons on selected lesson topics to her/his elementary class at assigned times over an 18-month period. The teachers were required to videotape each lesson, using portable videotaping equipment supplied for that purpose by the Institute. The lesson assignments were scheduled to provide a basis for comparison of the extent to which each of the teachers used hands-on-science teaching techniques prior to, during, and after being instructed on their use. A total of 64 lessons (four each for 16 teachers) was videotaped and submitted to the ESEI faculty for review. This study required the development of criteria for the quantitative and qualitative assessment of the teachers' use of concrete manipulatives and the nature and extent of student involvement. The resultant evaluation instrument was designed for use by a jury of reviewers, who would examine patterns of teacher behavior and pupil involvement from the videotaped lessons. A jury of three evaluators with strong backgrounds in teacher evaluation and hands-on-science instruction was selected to view the taped lessons and compare teacher performance. The results of the study indicated substantial transitions from the use of traditional student-passive teaching techniques to student-active methods. The evaluation instrument developed for this study is keyed to the use of concrete manipulatives in elementary science teaching. Given the growing interest in hands-on-science instruction across the nation, instruments of this sort that are keyed to evaluating the use of concrete manipulatives in classroom teaching will become increasingly important for teacher evaluation.

THE EFFECTS OF AN STS TEACHER EDUCATION UNIT ON THE STS CONTENT ACHIEVEMENT AND PARTICIPATION IN ACTIONS ON STS ISSUES BY PRESERVICE SCIENCE TEACHERS

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The purpose of the study was to assess the effects of an STS teacher education unit, which was part of a science teaching methods course, on the STS content achievement and participation in actions on STS issues by preservice science teachers. It was hypothesized that completion of the STS education unit would result in higher STS content achievement and participation in actions on STS issues among preservice science teachers. The non-equivalent control group quasi-experimental design was employed using two sections of secondary science teaching methods. The experimental treatment was delivered over seven class periods, each 2 1/2 hours in length, during weeks 7 through 11 of the semester. It included elements which corresponded closely to the four-level goal structure for STS education. The control group completed instruction on the science laboratory. Data were collected pre-treatment and two weeks post-treatment using the Questions About Science, Technology and Society (QASTS) and the Actions Taken on Societal Issues (ATSI) instruments. The QASTS is a 37 multiple-choice item instrument, with established content validity and an Alpha reliability of .67, which assesses STS content achievement. The 47 item ATSI yielded four scores on the STS actions taken by the preservice teachers over a two week period, i.e., the number of actions taken, the number of actions for which there were opportunities but which were not taken (Non-Actions), the total number of actions and non-actions, and the ratio of actions to total actions taken. The ATSI has established validity and an Alpha reliability of .89. The equivalence of the experimental and control groups was established on relevant criterion variables. Repeated measures analysis of variance of the QASTS data yielded non-significant main effect F values, and a significant interaction F value ($F_{32,1}$, = 10.92, p = .002). Application of Tukey's HSD Test showed the pre to posttest gain on the QASTS in the experimental group (M_{pre} = 23.68, SD = 3.77; M_{post} = 25.75, SD = 3.62) to be statistically significant at the .01 level. Analysis of the ATSI data yielded non-significant main effect and interaction F values. The experimental treatment was found to be more effective in helping preservice science teachers develop STS content achievement than was the control treatment. The experimental and control treatments did not differentially affect participation in actions on STS issues. Science teacher STS education needs to fully address each of the four STS goal levels, especially the STS action skills level, to increase science teacher participation in STS issues resolution. The experiences and insights gained from participation in STS issue resolution will better prepare science teachers to teach STS, plus facilitate their development into "good" models of STS behavior for students.

THE INFLUENCE OF METHODS INSTRUCTION ON THE BELIEFS OF PRE-SERVICE ELEMENTARY AND SECONDARY SCIENCE TEACHERS: PRELIMINARY COMPARATIVE ANALYSES

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This study was designed to utilize qualitative and quantitative research techniques to: (1) determine the beliefs of pre-service elementary and secondary level science teachers before and after participation in a science methods course, (2) describe the changes in pre-service teacher beliefs resulting from participation in a science methods course, and (3) compare and contrast the belief structures of pre-service elementary and secondary level teachers both before and after completion of a science methods course. The data collection and analysis techniques used consisted of the repertory grid technique fortified with factor analysis. Because all of the data were generated by the students themselves, the potential distorting influence of researcher-imposed perspectives was minimized. Twelve pre-service secondary level science teachers enrolled in the same science methods course in Florida and 12 pre-service elementary level teachers enrolled in the same science methods course in Alabama participated in the study.

The pre-service teachers' beliefs were elicited in interviews conducted both before and after the completion of a designated methods course during the 1987-1988 school year. During each interview, each student generated and completed a repertory grid matrix representing the behaviors characteristic of his/her own teaching practices and the underlying reasons for these behaviors. Each set of grids was analyzed using a computer generated principal components analysis with varimax rotation.

Preliminary analysis of the data indicates that the elementary level pre-service teachers' science oriented belief structures focus primarily on concerns about their own welfare and adequacy as teachers. Until they gain a measureable amount of experience, these SELF concerns will most likely predominate over higher level TASK or STUDENT oriented impact concerns. A similar analysis of pre-service secondary science teacher beliefs indicates that their belief structures favor a hierarchy in which higher level STUDENT impact and TASK concerns predominant over SELF concerns.

Regarding the broader areas of focus, TEACHING and LEARNING concerns appear to be most evident in the elementary teachers' belief structures while TEACHING and SUBJECT concerns receive the most emphasis in the belief structures of the secondary teachers.

The number and diversity of sub-categories included in the factors generated both before and after completion of the methods course seem to be as diverse and unique as the individual students themselves.

THE INFLUENCE OF PRESERVICE SECONDARY SCIENCE TEACHERS' BELIEFS AND KNOWLEDGE ON LESSON PLANNING AND TEACHING BEHAVIOR

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The reform of teacher training programs has been a concern of teacher educators in the 1980's. Traditionally, teacher education has focused only on changing teachers' behavior. Behaviors were observed and/or modified without great concern for the teachers' perceptions. However, in the past decade researchers have realized that teachers' thinking (their knowledge and beliefs) are important factors that influence their lesson planning and teaching behavior. In order to design a lesson plan, a teacher needs to use different kinds of knowledge. However, not much research had been done on how subject matter knowledge and knowledge of teaching influence teachers' lesson planning and teaching behavior. Most research on the effect of teachers' knowledge and/or beliefs on their lesson planning and teaching behavior focuses on elementary school teachers. Little has been done to study the combined effects of knowledge and beliefs or to determine their influence on preservice secondary science teachers.

This study was conducted over a period of six months. Three preservice secondary science teachers participated in the study. Researchers conducted interviews to collect data on their views about teaching. Field notes were taken during classroom observation to collect data on their teaching behavior. All lesson plans, classroom rationale papers, and journals were also collected. At the end, university supervisors and cooperating teachers were interviewed to collect alternative views about these preservice teachers' performance. All interviews were transcribed and analyzed by creating a coding system. Finally, the study tried to investigate how preservice secondary science teachers' beliefs and knowledge influence their lesson planning and teaching behavior to gain insight on preservice teachers needs in their training program. The results of this study indicate that preservice secondary science teachers strongly believe in teaching science process skills; they preferred to do group work in their classrooms; their pedagogical content knowledge depends on their knowledge of their students and their own experience.

INFLUENCING PRESERVICE ELEMENTARY TEACHERS' VIEWS OF SCIENCE THROUGH "SEARCH FOR SOLUTIONS" FILM SERIES

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Research indicates that preservice elementary teachers hold a view of science that differs from that held by members of the science community. In general, preservice teachers view science in a less tentative manner than scienctists do, and teachers' philosophical views of science may be a major factor in how they teach science in the classroom.

Results indicate that, although a preservice teacher's philosophical view of science could be influenced through a methods class, the generalizability of these results is limited. If readily available films could be evaluated in terms of enhanced teacher outcomes, then science educators would have access to validated effective instructional resources.

The efficacy of one film for bringing about a change in how science is viewed has been validated, while a second study designed to validate the efficacy of another film series shows no significant differences. Possibly the second series did not alter views due to the relatively high beginning scores of the students rather than because the films are not actually effective for altering the way science is viewed. This study further explores the possibility of influencing preservice teachers' views of science by using three films from the Search for Solutions film series.

Elementary preservice teachers in their first education course were randomly assigned to treatment in a Solomon four group design. The order of the films was random, and the treatment was limited to the viewing of the films. No instructional time was spent on introducing the films or in discussion after the films. The treatment involves the films themselves, not how they are used in instruction.

Dependent and independent t-tests were conducted, comparing pre- and posttest scores. The results indicate that the pretest had no sensitization effect. The treatment group was pooled and the control group was pooled to increase the N and dependent and independent t-tests were conducted, comparing pre and posttest scores.

The results indicate that the film treatment did influence the preservice teachers' view of science as measured by the VOS, but not in the expected manner. Students scored significantly lower on the posttest after viewing the treatment films than they did on the pretest administered before the films were shown, and yet the pretest did not sensitize the students.

These results indicate that it is possible to alter preservice teachers' views of science. The results validate the efficacy of the film, "Knowledge or Certainty," from the Ascent of Man series as increasing this tentative view, and the three films, "Theory," "Trial and Error," and "Evidence," from the Search for Solutions series in reducing this tentative view or moving their view further from the science community's general view of the tentative nature of science.

THE INFLUENCE OF PROFESSIONAL EDUCATION AND INTERNSHIP EXPERIENCES ON THE BELIEFS OF PRE-SERVICE SECONDARY SCIENCE TEACHERS

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This study was designed to: (1) determine the beliefs of pre-service secondary science teachers prior to the completion of professional education coursework, after the completion of this coursework, and following the completion of intensive internship experiences, and (2) describe the changes in these beliefs resulting from participation in professional education and internship experiences. The data collection and analysis techniques used consisted of the repertory grid technique fortified with factor analysis. Because all of the data were generated by the students themselves, the potential distorting influence of researcher-imposed perspectives was minimized.

Twelve pre-service secondary science teachers enrolled in a graduate level teacher preparation program participated in the study. All of the participants had bachelor's degrees in their respective subject areas.

Data collection involved three sets of interviews conducted over an eight month period. Each set of interviews consisted of two phases. During phase one, each student generated and completed a repertory grid matrix representing the behaviors characteristic of his/her own teaching practices and the underlying reasons for these behaviors. Each set of grids was analyzed using a computer generated principal components analysis with varimax rotation. During phase two, each student reviewed his/her respective factor structure and developed a label and an accompanying written narrative describing each factor and its constituent constructs.

The factor structures and their accompanying student-generated interpretations were analyzed on two levels. First, they were reviewed to determine the major categories and sub-categories of focus. Second, individual and collective comparisons were made between the organization and content of the factor structures and narratives at each of the three phases of the teacher preparation experience.

The mean number of factors generated ranged from 3.00 for entry level grids to 4.42 for post-internship grids. The mean number of constructs included ranged from 9.92 for entry level grids to 14.33 for post-internship grids. When factors and their component constructs were examined, two specific and three broad categories of focus were identified. Specific categories included concerns related to: (1) the outcomes, needs, or characteristics of "STUDENTS" and (2) the "TASK" of teaching. Broad categories included concerns regarding (1) the role of teachers and the value of "TEACHING," (2) the value of "LEARNING" in general, and (3) the importance of "SCIENCE" as a subject.

All 12 preservice teachers' belief structures reflected a primary emphasis on STUDENT concerns in all three analyses. TASK concerns were present in the entry level grids of 10 students and in the post-professional education and post-internship grids of 8 and 11 students, respectively. The number of sub-categories of both STUDENT and TASK concerns was greatest in post-internship grids. Beliefs reflecting the broader areas of focus were less prevalent than specific ones for all three sets of analyses. Overall, TEACHING concerns were most common, followed by SUBJECT concerns and LEARNING concerns. The number of sub-categories of both TEACHING and SUBJECT concerns was greatest in post-internship grids.

THE EFFECT OF AN IN-SERVICE TEACHER EDUCATION PROGRAM ON ELEMENTARY SCIENCE TEACHING

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This study determined the effect of an in-service teacher education program on participants' attitudes to science teaching and on their ability to handle obstacles to teaching elementary science. Sixteen elementary teachers participated in a year long in-service certificate in the teaching of science program.

The pre-test comprised an attitude to science teaching scale, an interview, and the first teaching practice session. At the end of the program the post-test comprised the attitude scale, the final teaching practice, and an interview. Changes that occurred between the commencement of the program and the completion were carefully recorded and analyzed.

The treatment comprised 50 contact hours in each of the following:-

(1) Foundations of education
(2) Concepts in science - content needed to teach elementary science
(3) Teaching of integrated science - strategies and skills to teach elementary science
(4) Practicum - practice in teaching elementary science
(5) Research methods

Pre-program interviews indicated that participants lacked background knowledge, skills, and confidence in teaching science. One of the greatest obstacles to teaching science was lack of materials and equipment. Participants admitted being confused by science equipment, were unable to construct material, felt that students did not understand when they taught science, and that their background was inadequate for effective elementary science teaching. Their attitude to science teaching was negative.

As part of the program, participants developed equipment needed to teach the existing elementary science program using locally available material and conducted a 3-hour workshop for 40 teachers on how to use the equipment. They also participated in making a slide-tape presentation on "Developing Equipment for Elementary Science Teaching." The workshop was very successful and slide-tape presentation will be used with participants at other courses.

Post-program interviews revealed that the participants' lack of background knowledge, skills, and confidence changed significantly. A comparison of the pre- and posttest attitude to science teaching scale showed a most positive change at the .001 level of significance. Teachers who at the start of the program were either hesitant or refused to teach were now eagerly demonstrating teaching strategies to peers and incoming teachers. Participants felt that the program had helped them to improve their science teaching, especially in the areas of how to teach science, how to manage a class while teaching science, and how to develop equipment. Teachers also reported a transfer of the skills acquired in the program to other subjects in the school curriculum.

USING QUANTITATIVE AND QUALITATIVE EVALUATION METHODS TO COMPARE TEACHER INSERVICE PARTICIPANTS' AND NON-PARTICIPANTS' PERCEPTIONS OF THEIR MOTIVATION TO LEARN

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Both quantitative and qualitative evaluation methods were used to compare perceptions of teacher participants and non-participants of a Title II science up-date inservice program. The two evaluation methods presented a more complete understanding of the participants' and non-participants' perceptions of their motivations to learn.

The purpose of this article is to compare the SSI teacher participants' and a selected non-participants' perceptions of their motivations to learn. Qualitative evaluation methods were used to provide depth to the quantitative interpretations of the results.

A two-week science up-date for 15 teachers (SSI) was conducted at Sioux Falls College in June 1988. A pre-inservice questionnaire consisted of motivation for learning items and questions from Teachers in Exemplary Programs (Bonnstetter, Penick, Yager, 1983). Demographic responses of teachers in the SSI group compared similarly to the exemplary teachers who participated in the nation-wide study. Results of the Science Attitude Inventory (SAI) indicated that teachers in the SSI group had similar attitudes toward science as the exemplary teachers in Bonstetter's study. Personal interviews were conducted with each participant. Follow-up elementary classroom visits by the principal investigator and additional credit for using information gained in the inservice were optional incentives provided for workshop participants. Each participant contributed a laboratory investigation to a handbook printed for participant use. A 6 month follow-up questionnaire ascertained the extent of perceived measurable change that had occurred as a result of the project.

A comparison group of 15 teachers, randomly selected from the non-participants were surveyed similarly to the SSI group. Statistical treatment included comparison of mean scores of, Likert scale items between the two groups and factor analysis of demographic data and pre- and post-treatment surveys.

CURRENT MODELS IN PHILOSOPHY OF SCIENCE: THEIR PLACE IN SCIENCE TEACHER EDUCATION

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The purpose of this study is to explore the need for a historically alive philosophy of science course for prospective science teachers as a way to improve their "cultural literacy" in various scientific disciplines; to evaluate the current status of such programs, both in terms of presence of such a dimension and degree of agreement with current philosophical models; and to offer a beginning framework to science teacher educators for a course in philosophy of science. The notion of finding models of scientific culture that are both descriptively accurate of how science is done yet normatively defineable is a challenge. It is, however, necessary that those who educate others about science have some flexible, composite framework in mind while espousing the virtues of their scientific discipline.

First, an extensive qualitative appraisal of the primary and secondary literature in both philosophy of science and science education was conducted to ascertain the value of such a dimension in science teacher education and what questions might be pertinent to those teachers. Careful consideration was given to works from varying philosophy of science "camps."

This was followed by a six-question survey of seventeen leading institutions, whose science education programs are known to have very active NARST members. Since some responded that their science methods courses were the place for such questions to be addressed, this was followed by a qualitative evaluation of ten current methods texts, both secondary and elementary.

As a result of the literature search, the seventeen-institution survey and the methods text evaluation, important questions in philosophy of science emerged which need to be addressed in science teacher education programs. The final contribution in this study is a beginning framework for a philosophy of science course for science teachers, which will eventually address specific important issues on the nature of theories, the quality of explanations, and how various confirmatory techniques differ.

INFLUENCE OF RESEARCH IN SCIENCE EDUCATION ON SCIENCE TEACHING PRACTICES: PERSPECTIVES FROM NIGERIA

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Science education as a field of study is ultimately concerned with producing a scientifically-literate citizenry. Its major focus includes assisting learners to develop knowledge and understanding of the world, desirable scientific skills and attitudes, and the recognition of the social functions of science.

In the course of its development, the discipline of science education has elaborated a number of theories through which norms for the educational process are established. A key ingredient in theory building is the research process through which data are empirically collected from which valid inferences could be deduced. In this paper, the nature of research in the area of science education in Nigeria is examined and the effects of the findings of these research efforts on the practice of science teaching are considered. Of all the publications reviewed, 101 (63%) were project reports (ACE, NCE, B.Ed), theses and dissertations; 301 (71%) were journal articles; 10 (20%) were books; 14 (38%) were proceedings of conferences, seminars and workshops; and 105 (10%) were seminar papers and pamphlets.

These publications were systematically examined for the following information: (a) the subject matter and area of science focused upon, (b) the principal research methodology employed, (c) the principal findings and recommendations for classroom practice. It could be said that many of the research findings and prescriptions for classroom practice have not been embraced or have been ignored by science teachers and those in positions to use research results.

Three probable explanations for the lack of use of the results by teachers may be advanced. In the first instance, it could be said that the characteristic inertia in response to change and innovations is an explanatory factor. It is said that teachers are characteristically resistant to any penetration by a new practice, no matter how well researched and promising the practice is.

Second, most teachers have low morale, poor self-esteem and public image, and lack motivation. The urge to put in additional effort in connection with new prescriptions based on research is hardly ever present. Thirdly, the teaching preferences of the teachers intervene in the adoption of research recommendations. Despite the recommendations for the use of the discovery learning technique, the use of advance organisers, learning hierarchies and the cooperative learning technique, teachers still impose their learning preferences and oftentimes jettison the new technique after a little while. A teacher's preferred way of teaching is based on the teacher's values or ideal teaching style and on the teacher's abilities and skills in teaching. A number of implications for science education researchers and science teachers are drawn in the paper.

EVALUATIONS OF A TEACHER TRAINING PROGRAM IN THE SCIENCE AND ETHICS OF RECOMBINANT DNA

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Multiple evaluation procedures were used throughout an extensive teacher training program in the science and ethics of recombinant DNA to provide formative and summative assessments of the program's effects. The program consisted of a four-day refresher preworkshop, a two-week wet lab and classroom implementation workshop (conducted at three sites), a three-day symposium on ethics and values, and follow-up support services during the academic year. Evaluation procedures addressed impacts on participants' knowledge, attitudes, and classroom implementation and participants' perceptions of the value of the program. Significant positive effects were discerned for knowledge and some attitudes; differences among sub-populations of participants were also found. Participants' responses to completed program components were very positive. Data collection on participants' implementation efforts during the current academic year continues. Portions of the data proved highly useful in modifying the program during its execution. Analyses also provided insights and directions for similar teacher training programs.

A QUANTITATIVE INVESTIGATION CONCERNING SCIENTIFIC LITERACY AMONG HIGH SCHOOL AND UNDERGRADUATE SCIENCE EDUCATION MAJORS

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An ERIC search covering the years 1962-1986 was conducted looking specifically for quantitative studies concerning scientific literacy of American high school and university students. Key words in the search were "scientific literacy," "understanding the nature of science," "content knowledge of science," and "science understanding." Over 100 of these studies were looked at in depth for consideration in a meta-analysis. Of these 100, four were selected as acceptable. Criteria for meta-analysis included:

1) Quantitative study - that is, an experimental and control group are present.
2) United States study - the study must have been done in the U.S.
3) The study needed to deal with high school or university students

Of the four studies, one was, itself, a meta-analysis looking at new curricula across elementary and high school grades and asking the question, "Do new science curricula increase students' scientific knowledge more than traditional curricula?". Further, in studies concerning scientific literacy, while there is a great deal of assessment work, definitions concerning scientific literacy vary from including strict knowledge level concepts of science to an understanding of the processes of science as well as computer and technological literacy.

Much concern has been raised in the past few years about the next generation of workers, who may, in fact, not be prepared to take over even menial jobs within a technocratic society. It is, therefore, the responsiblity of the science education community to not only define what we mean by scientific literacy, but to prepare future generations to be scientifically literate. This research utilizing the techniques of meta-analysis helps clarify what is meant by the term scientific literacy; and, more importantly, what has been found in the past 20 years to produce that scientific literacy.

Symposium

HISTORY OF SCIENCE, SCIENCE & SCIENCE EDUCATION: A REPORT OF ANOMALIES IN THE TEACHING AND LEARNING OF SCIENCE

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The symposium reports on the ongoing development and evaluation of a college-based science program that has adopted a depth over breadth approach to the teaching of science. The approach to science instruction in this course stresses the importance of using a historical perspective to study the development and the justification of knowledge claims and scientific concepts. The distinctive approach incorporates history of science into three instructional themes or storylines. Each of the themes is critical to what may be called the scientific view of the world today. These themes are: (a) the development of the idea of a solar system, the so-called heliocentric system of the planets; (b) the long and difficult process of realizing that matter is fundamentally particulate in nature; and (c) the manner it which it was recognized and accepted that the earth, and life on earth, are not unchanging as they seem, but have a history.

Adopting the historical storyline approach to the teaching of science has provided mixed results for students striving to learn science and for faculty striving to teach science. The four presentations of the symposium explore both the positive and negative factors related to science curriculum adopting the historical approach.

1. Foundations of Science - A Historical Storyline Approach. The first presentor will describe the theoretical foundations, the goals, and the organizational structure of the course. Examples of lecture topics, student assignments, and laboratory exercises are presented to develop an appreciation for the historical storyline approach. The instructional approach and curriculum are designed to enhance novice science students' understanding of the nature of science and of scientific reasoning as well as knowledge of some significant facts and relevant conclusions critical in the three themes. More specifically, the approach seeks to develop learners' knowledge about science.

2. Concepts of a Solar System in Tandem with Scientific Method. The second presentor will report on the integration of science concepts with science processes. The storyline of the emergence of the heliocentric theory of the solar system from the Babylonians to Newton is well suited for introducing the rudiments of a scientific method. The teaching of select concepts relevant to the development of theories about planetary motion can be effectively integrated with a discussion of the observational techniques used and their limitations and the evidence obtained to construct these theories. Thus, along with the emergence of the understanding that the planetary system is sun-centered rather than earth-centered, and that the entire universe is governed by the same set of rules, there simultaneously emerged a method for arriving at these conclusions.

3. Atomic/Molecular Structure - Logical or Chronological Order. The third presentor will address the perplexing problem of when and why it is justified to abandon the historical sequence in favor of a quick look at the big picture. Adhering strictly to the historical presentation of the development of a particulate view of matter was found to be difficult during the section of the course that covers the physical and chemical properties of gases. A compromise justified by the difficulties many prominent scientists actually had in accepting our current point of view may be to present science concepts in packages of time (e.g., 1850 to 1900) rather than looking at isolated individual events.

4. Double Indemnity - Students' Separation of History and Science. The last presentor will report the results of a preliminary study conducted with students in the course. Data suggest that learners are separating the historical story line from the science concepts of the course. Thus, it seems the students are not internalizing and/or integrating the conceptual changes embedded in the historical development of the storyline with their own learning. Given the assumption that the historical storyline would assist learners in bridging gaps between associated scientific concepts and in understanding the nature of science, these results are perplexing. That such bridging isn't occurring reinforces the positions that cognitive development involves conceptual change and that many mismatches exist between students' and teachers' perspectives of what is relevant.

Roundtables

ATTITUDES AND STEREOTYPING IN SCIENCE: TRENDS AND TRANSITIONS K - 12

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Current attitude measures have been criticized because of poor reliability, low correlations with other variables such as achievement, and differential responses to scales according to the grade and sex of the respondent. This research is the first part of a three-year study to develop a scale that addresses these problems. We are attempting to create an attitude measure that reflects student-generated scales based on student-generated concepts, rather than researcher-generated scales. To this end, 182 students (91 male, 91 female) in kindergarten through grade 12 were randomly interviewed by three researchers. The interviews were semi-structured and addressed the following topics: (1) attitude toward science and school; (2) instructional techniques, materials, activities, and strategies; (3) the nature of science and scientific work; (4) attitude toward women in science; (5) role specific self-concept; and (6) academic and career goals in science.

The first paper, Attitudes and Stereotyping in Science: Trends and Transitions K-12, focuses on attitudes toward science and women in science. Data from interviews suggest interventions that focus on both males and females. The data also suggest that, although interventions should take place from the moment children enter school, a crucial time is the junior high school age.

The second paper, What Did You do in Science Class Today? Children's Perceptions of What They are Doing in the Classroom, focuses on students' perceptions of what they are doing in the classroom. Both curricular and instructional issues are addressed.

The third paper, IF I WERE THE TEACHER. . . Student Preferences in the Science Curriculum, describes data from the semi-structured interviews as the researchers looked for periods of transition and explored sex differences, K-12. Talking with students revealed a complex and developing understanding of science. Its original and continuing allure is a free-form inquiry into nature that is unfettered by intellectual demands. It is self-guided and creative, and when this aspect of science is lost, science is abandoned for other activities. Three factors contribute to a

decline in attitude as the school years progress. These are changes in work load, the degree of ambiguity, and the level of abstraction that are associated with an increasingly sophisticated approach to science in the classroom. As we demand more of students, so do we alienate many who have enjoyed science in earlier grades but for whom it is not appealing in its newest form.

STUDENTS' INTUITIONS AND SCIENCE INSTRUCTION: A COLLABORATIVE RESEARCH PROGRAMME

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The purpose of this session is to describe some of the processes and the products emanating from a collaborative action-research program which has been focused on problems of science instruction in secondary schools. The session will consist of five presentations. The first presentation will lay out the theoretical and methodological stance of the project, while the remaining four presentations will be reports of specific case studies conducted by members of the project team and will illustrate some of the substantive findings of the project.

Briefly, the research program is informed by a constructivist perspective which we argue has clear implications for how one might construe the nature of teaching and learning. A prominent feature of this particular perspective is the importance which teachers must attach to "student constructions" both prior to and during instruction. Three of the case studies will be devoted to describing pedagogical exemplars, which are illustrative of instructional strategies aimed at identifying and modifying existing student constructions. A final case study describes some of the essential elements of a reflective practicum where members of the project team are working with student teachers. Implications for the theoretical perspective, the methodological stance and the practical outcomes will be integrated through-out the presentations.

Symposium

USING PORTFOLIOS TO CAPTURE THE PERFORMANCE OF HIGH SCHOOL BIOLOGY TEACHERS: THE WORK OF THE BIOLOGY COMPONENT OF THE TEACHER ASSESSMENT PROJECT

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The Teacher Assessment Project (TAP) at Stanford has been investigating alternate modes of teacher assessment. The results of this research will inform the deliberations of the National Board for Professional Teaching Standards. Among the assumptions that underlie the work are: teaching is a complex profession, teaching is done in a context, and successful teaching requires both theoretical knowledge and practical skill. The biology component of the Teacher Assessment Project (BioTAP) is conducting a study on the assessment of high school biology teachers. The mode of assessment reported on in this symposium is the development of a portfolio of evidence from teacher and student materials generated during the academic year. A portfolio is defined as a collection of documents that a teacher presents as evidence of competence in teaching. Several questions are being posed: 1) is the development of a portfolio a feasible mode of assessment; 2) how can teachers work with researchers to design and test the portfolio mode; and 3) what is the relationship required for teachers to work together to develop portfolios?

Twenty high school biology teachers with the assistance of an advisor are completing four portfolio entries: teaching a lesson, planning, evaluation, and exchange (professional discussion). While it would be premature and presumptuous to present final results of an extended research project that is still in progress, we have begun to uncover the answers to some of our initial questions. It is clear that, even with the great variability of documents presented in the portfolio and the variability of circumstances in which the candidates practice, there is an underlying substantive body of knowledge and skill that supports successful teachers.

This symposium has three objectives: 1) to describe the design of the study and the conceptions of teaching that underlie the work; 2) to share the results of the study; and 3) to describe three different roles that practitioners assumed during the study (developer, advisor, and candidate). The discussion among the participants will highlight the interdependence of research and practice in teacher assessment. The five papers that will be presented in this symposium each report on a different aspect of BioTAP from a different perspective. What is BioTAP - The Biology Component of the Teacher Assessment Project? will present an overview of the objectives and issues and report on the question of the feasibility of using a portfolio for teacher assessment. BioTAP: A Researcher's View will report on the design and conduct of the research and on issues raised about rating the documents in a portfolio. BioTAP: A Practitioner's View will report on the project from the perspective of a teacher involved in research design. BioTAP: Wearing Two Hats will be presented by someone with the roles of developer and advisor. The paper will report on relationships between teachers as they developed portfolios. BioTAP: The Candidate's Point of View will report on the project from the point of view of a subject.

Contributed Paper on Cognition

DEVELOPMENTAL PATTERNS IN LOGICAL REASONING OF STUDENTS IN GRADES SIX THROUGH TEN: INCREMENTS AND PLATEAUS

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The purpose of this descriptive study was to investigate the developmental patterns in logical reasoning of students in grades six through ten over a span of twenty months. The sample (N = 84) represented a proportion of a larger rural sample (N = 130). The Group Assessment of Logical Thinking (GALT) was administered to the sample during the Fall of 1986, the Fall of 1987, and the Spring of 1988. The GALT measures six reasoning modes (i.e., conservation, proportional reasoning, controlling variables, probabilistic reasoning, correlational reasoning, and combinatorial logic). Cronbach's alpha reliability was computed for each administration of the GALT. Frequencies, percentages, means, and standard deviations were computed on all test items, the six modes of reasoning, and total GALT scores for the three administrations of the GALT. The two-tailed t test was used to analyze gender differences on the six reasoning modes and GALT total scores. Also, the ANOVA statistic (GALT score by grade level) was computed per test administration. For the three administrations of the GALT, correlational reasoning was found to be the most abstract for the total sample. Only those students in grade seven (n = 17) and grade eight (n = 22) found probabilistic reasoning to be the most abstract on the 1988 administration of the GALT. The results of the two-tailed t test for gender differences were not significant. The ANOVA (GALT score by grade level) was significant at the .01 level for each test administration. None of the students who were first tested in grade six, seven, or nine attained formal operational reasoning as measured by the GALT. The number of formal operational reasoners for the original grade eight group remained constant throughout the three test administrations, but the number of transitional operational reasoners increased. For the grade ten group, a decline in the number of formal operational reasoners was found from the first test administration to the last test administration. The results seem to indicate (a) the majority of this sample are not functioning at the formal operational reasoning level, (b) a significant movement from concrete to transitional operational occurs at the end of grade seven, and (c) a plateau effect occurs between grade eight and nine.

PRACTICALS AND THE ACQUISITION OF ACADEMIC SKILLS IN THE NATURAL SCIENCES

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The Prime Minister's Committee on Natural Science in Education in Great Britain reported in 1918 that "...in many schools more time is spent in laboratory work than the results obtained can justify." Seventy years later this conclusion can often still be drawn. This is particularly a problem in open distance education where practicals, due to philosophical and logistical reasons, must be kept to a minimum and where their implementation must be both effective and efficient. Practicals do not usually justify their costs because they are all too often used to achieve the wrong goals. They often focus on the illustration or affirmation of the substantive structure of science, whereas their strength lies in the teaching of the syntactical structure of that same domain. Three common but faulty motives for practicals will be rejected and three new, more valid ones will be presented in their place. Finally, three types of practicals will be introduced and paired, on didactic grounds, to the three valid motives.

USING QUALITATIVE AND QUANTITATIVE METHODS IN A STUDY OF HIGHER-LEVEL COGNITIVE LEARNING IN GRADE 10 SCIENCE CLASSROOMS

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Although higher-level cognitive learning has been an intended outcome for many years, the goal appears to have been elusive. Consequently, a team of six researchers made higher-level learning the focus of an intensive 10-week study of two science teachers from the same school. Qualitative information was obtained from direct observation of approximately 80 lessons by one or more researchers, interviews with students and teachers, and inspection of student workbooks and assessment items. Quantitative information was obtained from questionnaires assessing student attitudes and perceptions of classroom environment and from systematic observation of types of activities and engagement patterns. Overall the various qualitative and quantitative methods blended together to provide a composite picture of classroom life. In this paper, the focus is the marked differences between two teachers in terms of classroom activities, engagement patterns and psychosocial environment and how these differences are consistent with observational data and the metaphors which the two teachers adopted to characterize their teaching.

A COMPARATIVE STUDY OF LOGICAL THINKING SKILLS: WEST GERMANY DATA

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The Group Assessment of Logical Thinking (GALT) instrument has been widely used to gather cross-cultural data regarding the acquisition of logical thinking skills in adolescent children. To date, American, Japanese and Philippine data have been compared and reported in order to discover underlying educational and cultural similarities and differences. This study of West German adolescents using the same instrument adds further comparative data regarding the development of logical thinking skills. In addition, the variables of time spent in learning science and mathematics were used to determine their relationship to logical thinking.

Analyses and comparisons of the results indicated the following:

1) Logical thinking skills develop progressively with age over the ages 12 to 15 years. While research has shown that individual students often regress for a period of time, the overall pattern over each of the cultures tested show a rather steady acquisition of logical thinking skills.
2) North American, Japanese, Phillipine and German data all show that boys score significantly higher than girls at each of the age levels tested. While these results may not be culture-free, they appear to be culture-independent. No testable explanation for this consistent cross-cultural phenomenon has yet been suggested.
3) The amount of mathematics or science taken each week in the German sample ranged from two to seven hours. While there was not a significant relationship between the hours of mathematics and logical thinking, the relationship between the number of hours of science instruction and logical thinking was highly significant. This result, while not a confirmed cause and effect finding, is of great interest to science educators who have suggested that activity oriented science is best suited to the development to logical thinking skills.
4) Based on the reasonable assumption that grade level and chronological age can be equated without seriously affecting the data analysis, it was found that German students scored between Japanese and American students at the same ages, and that differences between each of the cultures tested were significant. The very weak performance on correlational reasoning of all students appears to be caused more by an instrument anomaly than an indication that correlational reasoning is the last skill to develop among adolescent students.

While there are some differences across cultures in each of the specific sub-skills in logical thinking, there are certainly more similarities in the patterns of how adolescents develop logical thinking skills than differences. That the proper teaching of science can help students acquire thinking skills has been postulated by many science educators as well as others. The results of this study in West Germany lend support to this hypothesis.

LINKING GENDER-INEQUITY TO EDUCATIONAL PRODUCTIVITY ON THE INTERNATIONAL SCENE

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The objective of these studies was to determine the causal links related to the math achievement of fifth and sixth grade children in four countries (Greece, Japan, Republic of China, and the U.S.A.). Within each of these countries how much of their math achievement is related to parental influence? Does parental influence differ for boys and girls? Are academically talented daughters treated differently than boys in each country? Does the educational level of the parents have an effect on achievement? How are these variables interrelated with such factors as parental pressure, psychological support, parental help, press for intellectual development, and parental monitoring? How do the children's math self-concept and their attributions connect with these variables?

Finally, how do all of these variables interact and eventually fit into the gender inequity model that we have developed to explain the gender inequities that currently exist in the technical fields? This paper set will look at the gender differences across the four countries, and within the U.S. across the subsamples (Asian-Americans, Greek-Americans, Hispanic-Americans, and other Caucasian groups).

All of the studies were developed within the same framework -- Campbell's gender inequity cycle. Campbell has isolated an inequity cycle that helps explain why females and certain minorities avoid careers in the technical areas (engineering, science and mathematics). The cycle starts with parents exerting different influences on males and females all through their developmental years. These social-psychological forces are reinforced by elementary school teachers and peers and cause males to develop stronger math and science academic self-concepts.

These self-concepts foster heightened interest in mathematics and especially in the sciences and result in the development of a technical orientation (between grades 4 and 7). Such an orientation leads to the enrollment in advanced technical courses at the high school level. By pursuing the more rigorous courses at the high school level, such students achieve higher Scholastic Aptitude scores (especially SAT-M) which qualify them for the more prestigious technical colleges. Once they are admitted to such colleges they tend to major in the technical areas and go on to become scientists, engineers or mathematicians. The cycle is repeated generation after generation as parents continue to provide the same sociopsychological forces to their offspring.

The studies within this paper set used many of the same instruments. The parent data were derived from administering the Inventory of Parental Influence (IPI). This questionnaire was initially developed by factor analyzing (Principal Factoring with iterations) data from different samples of American, Japanese and Chinese children. Five factors emerged from these analyses which were named: parental pressure, psychological support, parental help, press for intellectual development, and monitoring/time management. Coefficient alpha reliabilities were found to range from .63 to .83 for the factors.

The math self-concept and attribution data were derived from the Self-Concept Attribute Attitude Scale (SaaS). This instrument was also developed by factor analysis (Principal Factoring with iterations) after being administered to 1300 gifted and nongifted students. SaaS contains five subscales (Coefficient alpha reliabilities): Math Self-Concept ($r = .89$), Success due to Ability (Success-Ability) ($r = .65$), Success due to Effort (Success-Effort) ($r = .69$), Failure due to a lack of Ability (Failure-Ability) ($r = .72$), Failure due to a lack of Effort (Failure-Effort) ($r = .70$).

The data were analyzed using partial least squares path analysis (PLSPath) as developed by Sellin. In these analyses, the latent variables are estimated within the program by the manifest variables. In this case, the predictor variable, the IPI factors, Self-Concept and Attribution scales were estimated by the answers to those questions that comprise that factor, using the outward estimation procedure. In addition to the IPI factors, the other predictor variables were sex, enrollment in a gifted program (there are no gifted programs in Greece), parent's education and parent's SES. The dependent variables were combined into a latent achievement variable. Separate analyses were conducted for boys and girls.

The results of these studies do show that parents reinforce the socializing efforts of peers and elementary school teachers. We are not certain where these forces begin, but it is clear that peers, teachers and parents all socialize the children -- especially girls in the same direction (except for the Chinese gifted). Caucasian females are particularly effected by such influences and these forces seem to orient them away from the technical areas. Furthermore, the study shows Caucasian females to be

influenced differently than the Asian-American females and from the high achieving male groups. The Greeks socialize the boys and girls differently, the boys are pushed toward success, while the girls, if they do succeed, do so by themselves. These differences are then compounded in their further education (junior high school, high school and college). The net effect of such differences could produce the gender inequities that we find in the technical areas. All of these data lead us to conclude that Campbell's gender inequity cycle is an accurate conception of this problem.

A SYMPOSIUM ON STS: WHAT IS IT AND ITS RESEARCH AGENDA

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This symposium will address a problem - what is STS? Since the 1982 National Science Teachers' Association position paper, which recommended that up to 20 percent of science instructional time should have a STS orientation, K-12 teachers have attempted to meet this goal. However, there is a lack of an operational definition to facilitate this identity. Consequently, some teachers might consider an acid rain instructional sequence to have a STS focus while others would not consider it STS.

The symposium speakers will address the identity problem and propose a STS research agenda for the 1990's. This research orientation will provide rationale for evaluation of the STS movement and impact in the first decade of STS research.

DEVELOPMENT AND EVALUATION OF A MODEL INSERVICE PROGRAM FOR SECONDARY SCHOOL SCIENCE TEACHERS

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This project involved 50 teachers (25 during the summer, 1987, and 25 during the summer, 1988) who participated in a Masters Teachers Institute in biology, chemistry, and physics. The instruction, which carried five hours of graduate credit from the University of Oklahoma in science and science education, was conducted in the science laboratories of the Norman Public Schools by three secondary school science teachers and the project directors. A chemist, a physicist, and a zoologist served as consultants and instructors as needed. Each teacher completed the study of at least two of the three curricula and spent one hour per day studying the science and learning theory-bases upon which the curricula are constructed. Upon completion of the summer institute, the participants returned to their schools to implement the learning cycle curricula.

The first paper, A NSF Summer Institute for Master/Science Teachers, examines the three major aspects of the general plan of a NSF-sponsored institute for master science teachers: 1) the science curricula - learning cycles in biology, chemistry, and physics; 2) design of the institute; and 3) selection of the participants.

The second paper, Evaluating the Effectiveness of a Model Inservice Workshop for Secondary Science Teachers: The Students, discusses the determination of the efficacy of using student achievement as a means of evaluating summer teacher enhancement workshops. At the conclusion of the workshop, six teachers were selected for involvement in the follow-up evaluation. In addition, a questionnaire sent to other science teachers in the participating schools provided the basis for the selection of six teachers to serve as a control for the study. Student achievement was evaluated by (1) pre- and post-testing with a published standardized test and (2) analyzing student responses to concept evaluation instruments. Analysis of the procedures of the study indicated that variables such as student participation, teacher participation, and teacher integrity affect the acquisition of the data and subsequent validity of the results.

The third paper, Evaluating the Effectiveness of a Model Inservice Workshop for Secondary School Science Teachers: The Teachers, reports on the evaluation of the effectiveness of a model inservice teacher workshop by assessing changes in participants' attitudes and understandings relevant to the curriculum and instructional method presented in the workshop. Questionnaires were used to gather pre- and post-workshop methodological and philosophical data from the participants and from a comparison group. Participants' levels of understanding of Piaget's learning theory were assessed at the conclusion of the workshop, and degrees of implementation of the curriculum by the participants were monitored during the following school year. Significant changes in participants' attitudes toward learning outcomes and instructional tools and in their philosophies of teaching occurred between pre- and post-workshop assessments. These changes in attitudes were congruent with the learning theory upon which the workshop was based.

Roundtables

MIDDLE GRADES SCIENCE TEACHER EDUCATION: ACADEMIC AND PROFESSIONAL DEVELOPMENT

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Little is known currently about the entry level knowledge and attitudes of students beginning preservice science and teacher education programs. In addition, how and to what degree these students change as a result of their teacher education experiences is also an enigma. Significant changes, not merely acquisition of knowledge, in the areas of academic and professional development are essential to transform a college student into a teacher.

The National Science Foundation (NSF) in 1986 solicited proposals for the development of model teacher education programs in this area. In response to this solicitation, nine proposals were funded to develop, implement and evaluate model programs for the preparation of middle grades science and/or mathematics teachers. The proposal funded at the University of Georgia recognized that many beginning teachers lack both the subject matter breadth and depth necessary to teach science. Thus this model program emphasized an increased amount of subject matter courses which stressed content appropriate to teaching in the middle grades. Three new courses in life, earth and physical science were developed and implemented. Students took these in addition to other education and science content courses. Secondly, and most importantly, each new content course was paired with a pedagogy course which stressed content specific pedagogy related to its matched content course. The courses were developed and taught by a team of scientists or mathematicians, educators and classroom teachers, with the latter providing the practical focus for the R&D effort.

The objective of this symposium is to report the status of preservice teachers' content knowledge and pedagogical knowledge, and their attitudes toward science and science teaching at the beginning of a teacher education program and to document the changes in these areas due to subsequent educational experiences.

THE TEACHER AS RESEARCHER

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The three papers in this session have a common focus in that they describe changes that occurred during six months in 1988 as a beginning high school teacher worked as part of a three-person research team studying her classroom.

The first paper, Improving Teaching by Changing the Metaphorical Basis for Conceptualizing Teaching Roles, is an interpretive investigation of science teaching and learning. It grew from previous research in science classrooms and from concern for a beginning high school teacher who was experiencing difficulties with the two classes she was teaching. A broad question concerning why the teacher could not do what she wanted in her classes provided a focus for the study. Data were collected on a daily basis for approximately six months during 1988. An important outcome of this study was that changing the conceptualizations of two teaching roles enabled the teacher to make changes in planning and implementation that resulted in a vastly improved curriculum.

The second paper, Alternative Perceptions of a Teacher Researcher, discusses the changes in the way the teacher conceptualized her roles and consequent changes in the way she managed her classes, planned and implemented her science program. How these changes were perceived by members of the research team, students, colleagues and administrators, and the teacher/researcher needed to be answered in order to learn more about the environments in which teaching and learning occur and the impact of change on these environments. The findings have implications for the design and implementation of interpretive research, particularly when teachers are members of a research team.

The third paper, Teacher-as-Researcher: The Inside Story, provides insight into the processes resulting in teacher empowerment and change which occurred. The paper is written from the first-hand perspective of a teacher/researcher involved in an interpretive study of teaching roles, and beliefs and values within those roles.

SCIENCE EDUCATION IN ELEMENTARY SCHOOL: "WHAT IS" AND "WHAT OUGHT TO BE"

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Educational decision makers are faced with increasing pressure to improve the quality of science education, yet little practical guidance exists for educational policy makers and practitioners.

Recently, the U.S. Department of Education provided three years of funding for the National Center for Improving Science Education, a partnership between the NETWORK, Inc. of Andover, Massachusetts and the Biological Sciences Curriculum Study (BSCS) of Colorado Springs. The National Center's mission is to promote change in state and local policies and practices in science curriculum, assessment and teaching. The Center uses study panels of scientists, science educators and other experts to synthesize and translate the findings. Recommendations and perspectives embodied in recent and forthcoming studies into practical resources for policy makers and practitioners. During year one, the Center examined elementary science education. This session is focused on the results of the Center's work.

The findings on the present state of science education in elementary school are described and recommendations made for how schools can bring about improvements. Three papers are presented, based on the work of the new National Center for Improving Science Education. The papers deal with the following aspects of science education in the early grades: curriculum and instruction, teachers and teaching, and assessment. The purpose is to put before the research and education communities the results of the Center's synthesis of research and practice and directions for moving forward from "what is" to "what ought to be" as specified by various commissions and experts in science and science education. The papers also report on some feasibility studies being conducted by the Center relevant to implementing some of the suggested improvements.

The curriculum and instruction paper outlines a conception of science and technology that guided the development of a proposed curriculum framework based on eight organizing principles of scientific knowledge. It also

presents a proposed instructional framework based on current knowledge of how students learn and of effective classroom practices. The teaching and teachers paper deals with four major issues: teacher quality, teacher preparation, professional development and the role of a school's organizational context. The paper on assessment describes how assessment can be used in the classroom and in the school to help improve science education. Four assessment issues were considered: the difficulty of assessing what we value most in student learning of science, the valid and invalid uses of assessment, synchronization between assessment for instruction and assessment for monitoring, and assessing the quality of a school's science program. The papers also report on several feasibility studies conducted by the Center relevant to implementing some of the suggested recommendations for improvement.

Bridging the gap between research, practice, and policy, the Center is committed to fostering cooperation and collaboration among organizations, institutions, and individuals concerned with improvement of science edcuation. The NARST session will serve as a forum for presenting and critiquing the Center's work, an important step in that process.

Symposium

METHODOLOGICAL ISSUES IN A MULTI-SITE, CROSS-COUNTRY COMPARATIVE STUDY OF ELEMENTARY SCIENCE IMPLEMENTATION

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This symposium provides an opportunity to address a variety of issues that emerge from a multi-site qualitative research study. The four persons who are part of this symposium are from four different countries and have been working together for the past one and one-half years on the development of a four-country comparative study of implementation and institutionalization of activity-based elementary school science programs. Within each of these four countries they are coordinating research done at a minimum of four different sites, producing case studies with results which subsequently will be integrated.

In addition to addressing issues arising in multi-site qualitative studies, the symposium provides a limited progress report on this cross-country comparative study which is expected to continue for another two years. This context provides a tangible example of a setting in which the given issues arise and within which the symposium members can explore alternative solutions.

The four country comparative study, known as IMPACT, is designed to identify barriers to activity-based elementary school science programs and means of overcoming these barriers and sustaining such programs over the long term, i.e., many years beyond an initial implementation effort.

In developing a multiple-site qualitative study of this nature, a number of methodological issues must be addressed. Given the number of sites involved (16 or more) and the variety of cultural settings (disbursed within four countries), these issues are of major concern. Among these methodological considerations are the following:

How does one develop common formats for data collection across these many sites and maintain the integrity of the qualitative approach?

How does one analyze these data, make valid cross-site comparisons and arrive at trustworthy generalizations that apply to some combination of these settings?

How does one take account of cultural differences in conducting a study of this nature across significant cultural boundaries?

A COMPARISON OF TWO INSTRUCTIONAL STRATEGIES INVOLVING SCIENCE LABORATORY ACTIVITIES

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The purpose of this study was to test the hypothesis that students introduced to new science information (diffusion and osmosis) through laboratory exercises learn and retain that information better than students taught through textbook readings or teacher lectures followed by verification.

The study group was composed of two ninth grade biology classes located in a suburban junior high school in Cincinnati, Ohio. The control group read and discussed diffusion and osmosis before performing laboratory exercises while the experimental class performed the lab before reading and discussing the concepts.

A pretest, immediate, and delayed tests were used to compare the achievement and retention of both groups. The tests yielded two scores. One score, called "relevant," was directly related to content in the laboratory exercises, which was supported by classroom discussions, and textbook readings. The second score, called "incidental," related to information included in classroom discussions and textbook readings but unrelated to the laboratory exercises.

Multivariate analysis of covariance was employed to compare the performance of students who experienced laboratory exercises before classroom discussions and textbook readings (experimental group) to the performance of students who experienced the same laboratory exercises after classroom discussions and textbook readings (control group). The dependent variables were immediate and delayed test scores. The textbook readings and classroom discussions were, as much as possible, the same for both groups. The covariates used were the pretest scores and scores on a standardized test called the Student Ability Index (SAI).

The results of the study are interpreted in terms of the information processing theory. In addition, recommendations for further research will be made.

A REVIEW OF RESEARCH ON SCIENCE LABORATORY INSTRUCTION AT THE COLLEGE LEVEL

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Only a decade ago, one would have found very little in the educational research literature on college-level laboratory instruction in the sciences. The few studies which were reported investigated primarily the value of laboratory instruction rather than specific approaches to laboratory instruction. Most of the studies compared laboratory to non-laboratory approaches or inductive to deductive laboratory approaches with inconclusive results. During the past decade, however, there has been much more research specifically on college laboratory instruction; the focus has been more on laboratory teaching strategies and learning outcomes. This paper is a summary of much of the available research on college science laboratory instruction of the past decade, grouped by some of the dominant areas being investigated.

A literature search was conducted on the topic of laboratory science instruction at the college and university level. All issues of the Journal of Research in Science Teaching, Science Education, American Educational Research Journal, Review of Educational Research, Journal of College Science Teaching and Abstracts from the annual meetings of the National Association for Research in Science Teaching since 1978 were hand searched for relevant articles. A computer search on the topic was also done from the ERIC data base. Thirty six relevant research articles were found and appeared to be focused in following areas: (1) inquiry or investigative laboratory strategies, (2) the development of reasoning and problem skills, (3) computer-based applications, and (4) other miscellaneous studies.

Some tentative interpretations from a review of the literature found are: (1) Inquiry or investigative approaches in college laboratory science courses appear to be generally productive. Newer and more innovative approaches over the past ten years were more student-involved, were more inductive and required more extensive use of science process skills. They generally produced significantly greater educational gains than the more traditional approaches. Nevertheless, the experimental novelty effect will continue to be suspected. (2) There is some evidence that students can be taught to improve their use of formal operational thought through the use of concrete, manipulative laboratory experiences. Some students designated as concrete thinkers can develop an understanding of concepts considered to require formal thought if given appropriate laboratory experiences. The more direct student involvement in all aspects of the laboratory activity, the more the student appears to learn. (3) Computer-based applications in the laboratory are of great interest to college science faculty and have, in some cases, shown to be as productive or more productive than the conventional laboratory exercise. Much more activity in both development

and research of this technology is expected. (4) Productive laboratory instruction in college science courses appears to be distinguished by having students engaged in science inquiry processes, by having the student engaged in the manipulation of experimental apparatus, and by teaching, simultaneously, science process skills and science concepts. More research on laboratory instruction in college-level science courses should be encouraged.

THE DETERMINANTS OF GRADES 3 TO 8 STUDENTS' INTENTIONS TO ENGAGE IN LABORATORY AND NON-LABORATORY SCIENCE LEARNING BEHAVIOR

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The Theory of Reasoned Action was used to investigate the intentions of grades 3 to 8 students to engage in laboratory and non-laboratory science learning behavior. The objectives were to determine (1) the salient beliefs (regarding the attitude toward behavior, or personal component, and the subjective norm, or social component) of the students concerning science learning, (2) the correlations between components of the theory, and (3) the relative weights of the determinants (attitude toward the behavior and subjective norm) of the intention to engage in the science learning behaviors. The study was exploratory, generating baseline information and employing correlational analysis. Elicitation session interviews were followed by construction of the two instruments (laboratory and non-laboratory), a pilot study, and then collection of data from 377 randomly selected students (187 laboratory and 190 non-laboratory).

Cores of salient attitudinal beliefs and normative beliefs were identified for the two behaviors. Several of the beliefs for laboratory and non-laboratory were identical. Attitude toward behavior and subjective norm explained significant amounts of variances in intention for both the laboratory ($R2 = .14$, $F[2, 184] = 16.78$, $p = .00$) and non-laboratory ($R2 = .25$, $F[2, 187] = 32.90$, $n = 190$, $p = .00$] behavioral intentions. The relative weight of attitude toward behavior was greater than the relative weight of subjective norm for both behavioral intentions. All correlations between the various other components in the Theory of Reasoned Action were significant ($p < .10$) for both the laboratory and non-laboratory behaviors.

This theory-generated baseline information could be used in several ways. Teachers of science could be informed of the cores of salient attitudinal beliefs and normative beliefs of these young science learners. Researchers might use this information to design experimental studies to test the effects of influencing salient beliefs and, ultimately, actual science learning behavior. The findings also suggest that researchers might benefit by investigating whether any limitations to the Theory of Reasoned Action are peculiar to its application to children.

Symposium

ETHICS IN FIELD-BASED RESEARCH

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For too long educational researchers have isolated themselves from educational practice and earned the reputation of having only esoteric, impractical answers to the problems of real science classrooms. The desire to abolish this gap between research theory and classroom practice has sparked an increasing interest in field-based research among science educators.

Although most researchers are aware of the standard meanings of informed consent and confidentiality, and there are codes of ethical principles published by such groups as the American Psychological Association, these codes provide little help with the problems that may arise in field work. Traditional approaches to ethics in research, focusing on the right of subjects versus the benefits of the research, were written to serve traditional research methods and are inadequate for addressing the dilemmas of field-based research.

Widespread use of interpretive research in studies of teaching and learning has highlighted a number of crucial ethical and legal issues. Although these issues have always been a concern for researchers, use of small samples and detailed analyses of teaching and learning have brought previously hidden aspects of teaching and learning into the public arena. As researchers endeavor to describe what happens in classes and probe to understand why these events occur, the beliefs, values and knowledge of teachers and students are inferred and used as a basis of grounded theory

for teaching and learning. Inevitably, some of these findings are not favorable to the teachers; a fact that is exacerbated by a growing number of case studies in which it is difficult or impossible to assure the anonymity of the participants. More recent work in ethics may be more appropriate for discussing the ethical dilemmas of field work because it suggests that we must also consider feelings, needs and impressions rather than simply universal principles.

Resolved and unresolved problems will be discussed as examples of the variety of anticipated and unanticipated dilemmas that arise. Possible solutions to these problems will be presented with illustrations of the varied reactions of participants in the research.

Symposium

MODELS OF COLLABORATIVE RESEARCH: UNIVERSITY FACULTY AND CLASSROOM TEACHERS AS PARTNERS AND PEERS

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The idea of involvement of teachers as active participants in research has become so popular that it has almost reached the status of a movement. It has brought a new perspective and new energy to science educators and new meaning to the NARST intention to improve science teaching through research. The idea of teachers as researchers and of projects and programs based on cooperative and collaborative arrangements has been a topic for papers, symposia and discussions at all recent meetings.

There comes a time in the evolution of an idea or concept when definition and clarification are needed in order for the idea to continue to be useful and productive. We seem to be at such a point now in the evolution of the concept of collaborative reasearch as a means of advancing science education.

The purpose of this symposium is to examine four models of collaborative research to identify common elements, to analyze the characteristics necessary for success, and to make explicit the goals and outcomes of the various models.

The four models to be presented are the following:

1) Teachers as Researchers at the Classroom Interaction Research Laboratory. The teacher researcher is creatively involved in the selection, design, implementation, analysis, and outcomes assessment of research programs. The role of the laboratory is to provide resources and consultation as well as support in data analysis and report writing.

2) Teachers as Equal Research Partners. Seven teachers and a faculty member worked as a team on a teacher-initiated ethnographic/interpretive study of students' perceptions about working in groups. Reactions of teachers, outcomes of the study and reflections on the project will be presented.

3) Academic Challenge Program: Collaboration in Innovation and Evaluation. The objectives of this program are a) to provide teachers with knowledge and experiences related to innovative teaching materials and methods and b) to provide teachers with knowledge and experiences related to classroom-based research so that teachers can successfully evalute and effectively use innovative teaching materials and methods.

4) New Wine in Old Wineskins: Incorporating New Technologies and Strategies into the Curriculum. The model was originally developed for the purpose of investigating the impact of tool software on the high school mathematics curriculum. It is now being used to investigate the impact of cooperative learning on the secondary science and mathematics curricula. The research question is "What can we do that we couldn't do before and how can we do it best?"

After presentation of the four models, discussion will be focused on the following questions:

1) What do the models have in common?
2) How are they different?
3) What elements in the models are necessary for success?
4) Is professional development or research productivity the goal of collaborative research?

Roundtables

RESULTS OF THE PRACTICAL LABORATORY PROCESS TESTS IN THE SECOND INTERNATIONAL SCIENCE STUDY

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Out of twenty-five countries which participated in the Second International Science Study (SISS) seven countries agreed to administer practical laboratory process tests to subsamples of 10 and 14 year old students. The results of these tests and their relationships with selected background, personal and school variables will be presented.

Following an introductory paper which will describe the general features of SISS as well as the specific practical tasks, their administration and assessment procedures, each of the seven participating countries will present an individual report. In each of these reports the following questions will be dealt with:

1. How do students perform on the different tasks?
2. What is the performance on specific process skills such as observing, investigating and reasoning?
3. What are the inter-relationships among the scores on various examined tasks and among different process skills?
4. What are the differences in performance between boys and girls?
5. What are the inter-relationships between performance in the practical tests and achievement in paper and pencil tests?

6. What are the relationships between performance in the practical tests and certain background, personal and school variables?
7. How can the results be explained?
8. What are the implications of the findings?

A final paper will offer a comparative analysis and suggest some general implications.

RURAL SCIENCE TEACHING: CHARACTERISTICS, PRE- AND INSERVICE PREPARATION, AND RESEARCH

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The purpose of this session is to present information concerning the problems and possibilities existing in the unique population of rural science teachers. Rural science teachers have needs and problems that are different from their suburban/urban counterparts. Historically, educators in general, and science educators in particular, have either ignored the unique needs of rural societies or have viewed them from a perspective far removed from the local community, using a set of standards much more applicable to large school systems. This session will be divided into four presentations which will address the following:

1) Rural School Characteristics;
2) Pre- and Inservice Preparation;
3) Rural Science Curriculum; and
4) Rural Science Education Research.

The first presentation will be centered around the unique characteristics of the rural setting. In this session topics such as isolation, facilities, community resources, and demographics will be discussed as they relate to teaching science. Teacher preparation will be covered in the next session. Emphasis will be on the special needs of rural teachers and how these are related to pre- and inservice programs. Suggestions will be made for the development of future programs. The third session will address the issue of science curriculum for rural schools. Consideration of the unique setting and special needs will be made and possible alternatives will be suggested. Finally, an agenda for rural science teaching research will be discussed. This agenda will factor in the unique setting, curricular needs, and teacher preparation.

This session will attempt to foster input from those attending. The topic of rural science teaching needs attention. It is hoped that this format will lead to action necessary improvement.

THE RELATIONSHIP BETWEEN THE DEVELOPMENT OF PROCESS SKILLS AND THE DEVELOPMENT OF LOGICAL THINKING

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The purpose of this session is to explore the relationship between science process skill development and the development of logical thinking. Questions that will be considered include:

1) Can logical thinking of students and teachers be increased by practice (or courses) emphasizing process skills?
2) Which instructional strategies are best for increasing the learning of process skills and/or logical thinking?
3) What effect does the initial knowledge of students have on their success with process skills?
4) Will teachers who have developed a mastery of process skills teach more effectively in their classrooms?

Previous research has shown a relationship between formal reasoning ability and science process skill attainment. It has been hypothesized that an increased emphasis on teaching process skills might enhance the formal thinking abilities of students. A variety of strategies are being proposed to better accomplish this task, most notably, The Learning Cycle approach. There has been little research in science education on the use of modeling strategies for promoting process development and/or logical thinking. The papers presented in this session deal with the overall relationship of Piagetian Theory to science process development. Furthermore, these papers deal with strategies for promoting more effective learning, teaching, and assessment of science process skills and/or logical thinking.

The first paper describes the effects of prior knowledge and Piagetian cognitive development on the process skill of prediction in The Learning Cycle. The think-aloud interview technique, modeled after Ericsson and Simon, led to the identification of 63 program exploration and prediction behaviors of different comparison groups (e.g. concrete versus formal, unsuccessful versus successful predictors, low versus high initial knowledge.) Successful predictors were found to have high initial knowledge of the subject matter and were formal operational.

The second paper reports on the effect of a preservice elementary school science methods course emphasizing mastery of science process skills on the level of development of formal reasoning. The experimental group significantly improved their developmental level of logical thinking after taking a one semester course emphasizing mastery of science process skills. Furthermore, these experimental subjects demonstrated a significantly higher overall level of logical thinking than a non-equivalent control group of subjects.

The third paper reports on a study of the effect of a middle school teacher inservice course emphasizing science process skills on the development of integrated process skills and logical thinking. A Resourcebook of Science Process Skills was developed for middle school students (grades 5-9) and was used with teachers in this inservice course. Significant gains were made by the teachers in both logical thinking and in their knowledge of integrated process skills.

The purpose of the study reported in paper four was to determine which of two teaching strategies would promote higher achievement of integrated process skills with urban middle school students. Furthermore, growth in the logical thinking of students was also measured. The two teaching strategies tried were: 1) a Systematic Modeling approach and 2) the Learning Cycle approach. Students of both the Modeling teachers and the Learning Cycle teachers outperformed those of a non-equivalent control group on integrated process skills. Modeling was found to be significantly superior to the Learning Cycle for promoting this achievement.

IMPLICATIONS OF WRITING-TO-LEARN RESEARCH FOR SCIENCE EDUCATION

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This session seeks to present the theoretical framework for writing to learn and three studies that represent the state of writing-to-learn research in science. Although the five presenters are from diverse fields and represent different research perspectives, all are closely involved in

writing-to-learn research. They share a common belief that writing empowers the writer (e.g. science students) with ability to explore their own understandings and the reader (e.g. the science teacher) with the ability to evaluate these understandings.

The first presentation reviews the theoretical frameworks currently being used for writing to learn across the curriculum (principally James Britton's), assesses their usefulness, and suggests an alternative theoretical model, based on classical rhetorical theory, Freudian psychology, and the psychology of invention. The purpose of the proposed alternative model is to supplement current cognitive and social theories of writing to learn by explaining, in a way useful for instruction, the processes of information gathering, of unconscious relation-making, and of the breaking into consciousness of new knowledge.

The proposed theory will delineate differences between knowledge of content and knowledge of process, or what philosopher Martin Greenman calls "what is encountered" and "ways of encountering." As such, it is useful for curriculum design using writing to learn, and for evaluation of learning through writing.

This presentation has important implications for science education. Science as a discipline is defined by the questions it asks, the degree of certainty it seeks, the kinds of evidence it accepts and the reasoning processes it allows. According to the theoretical framework of the proposed model, writing requires that the writer understand the rules which define science and at the same time provides the mode by which this understanding is developed. In addition, writing allows the progress of the writer's concept formation to be evaluated and directed.

It is the outcome of writing, a reader's ability to identify and describe the writer's process or level of concept development, that is the focus of the second presentation. For purposes of instructional planning and evaluation, it is important that teachers know where students are in their progress from primitive to more sophisticated concepts. The "close reading" of student writing is a method of assessing students' concepts. In the process of describing and interpreting an experiment, for example, a writer must make numerous decisions--at the word, sentence, and discourse levels--about what to say and how to say it, and these decisions are likely to be influenced by conceptual as well as communicative considerations. Consequently, the written product can serve as a kind of complex coordinate system for getting a "fix" on the writer's current thinking about content.

The third presentation is a report of the results of a nationwide survey, through the writing projects, to identify the kinds of research science teachers are conducting and report on their findings. Results of earlier informal surveys indicate science teachers who incorporate writing into their science programs discover that the process of writing and the scientific method have much in common. Many science teachers say writing activities allow them to teach science as concepts instead of science as a body of knowledge. Some say it has prolonged their careers.

The fourth presenter is in the midst of studying science teachers' attitudes and beliefs about their own writing and teaching and evaluating writing in science. This presentation will be a preliminary report. An attitude questionnaire was distributed to middle and secondary science teachers in twenty-three Georgia school systems. Results of the analysis will be discussed along with initial reactions to the follow-up interviews and classroom observations.

INTERACTIONS OF EPISTEMOLOGY AND ETHICS IN SCIENCE EDUCATION: CRITICAL ISSUES IN A PERIOD OF CHANGE

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This session was organized to examine some of the ethics and values decisions implicit or explicit in science teaching. As we as researchers struggle with issues of how constructivist curricula in science might appear and begin to implement instruction based on constructivist models of learning, we are finding we must deal with issues of ethics that are often obscured in traditional science teaching. As the papers will point out, values decisions and ethical dilemmas are present in traditional instruction and models of research. However, 1) these decisions are often hidden because they are part of traditional norms of science teaching and research and 2) if a constructivist perspective actually has potential to affect profound change in learners, as many of the participants believe, we must address the consequences of these changes in the learner and look at how these consequences are addressed in educational systems by students, by teachers, by family and by administrators.

The first paper in the session will present the argument that the model of the learner a teacher or researcher elects is essentially an ethical decision. The author points out ethics and values assumptions in both information processing and constructivist paradigms for learning and argues that decisions between these paradigms are values decisions. The author of the second paper, a central figure in Project 2061, will address values decisions made in the development of this large scale curriculum project with an explicitly constructivist view of the nature of scientific knowledge. The third paper will address the ethical dilemmas involved in implementing a constructivist teaching philosophy given large courses, a set syllabus, traditional texts and colleagues, time limitations, multiple sections of the same course, and other constraints of typical university science and mathematics departments. It will also address the ethical decisions involved in explicitly attempting to change individuals' beliefs about the nature of science and mathematics and some of the profound consequences of such changes. The fourth paper will describe ethics decisions in traditional teaching and research practices, such as the relationship between teachers and students, in terms of a cost-benefit analysis. The fifth paper argues for explicit attention to ethical issues in science instruction and negotiation of standards of ethical practice in science teaching and learning.

There has been little research or discussion of these issues of ethics and epistemology in science education. The final paper in the symposium will analyze and attempt to synthesize the perspectives and issues raised by the first five papers, as well as areas where research and discussion are needed, but currently lacking.

SCIENCE EDUCATION IN THE 1970S AND THE 1980S: WHAT CHANGES HAVE TAKEN PLACE?

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This is a study of science achievement in 1970 and the 1980s. The study found the following results:

1. On items common to 1970 and 1983 tests, the 5th, 9th, and 12th grade students in 1983 scored higher on life and physical science items, on items requiring process skills, and on items with visual illustrations.
2. Fifth grade students in 1986 scored about the same as their 1970 counterparts, but the ninth grade students in 1986 scored lower than their 1970 counterparts.
3. The ninth graders in 1983 and 1986 did not improve as much as ninth graders in 1970 when compared to their respective fifth graders from the same years. The fifth graders in 1983 were better prepared in science than their 1970 counterparts, while the 1986 fifth graders were equally as well prepared as their 1970 counterparts.
4. The growth in science achievement from 9th grade to 12th grade was the same in 1983 and 1984 as in 1970.
5. This study also found that 12th grade students not taking science had about the same science achievement as 9th graders.
6. The pattern of achievement on the items showing the highest and lowest student scores, as well as those showing the most and least amount of student improvement, remained essesntially the same in 1983 and 1984 as in 1970. The exception was on environmental topics, which appeared to be introduced in the schools at an earlier level in the 1980s.
7. The 1983 students scored lower than their 1970 counterparts on word knowledge test items. Again, there were no changes in gender differences in Grades 5 and 9, and for 12th grade students who were not studying science in the 12th grade. The only change showing a gender difference favoring girls came from the 12th grade students not taking any science.
8. The students in the 1980s did less homework, watched more television, expressed lower aspirations for college, and enjoyed school more than their 1970 counterparts.

A CONCEPTUAL FRAMEWORK FOR INCORPORATING TOPICS FROM THE HISTORY AND PHILOSOPHY OF SCIENCE

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This paper presents a conceptual framework for integrating history and philosophy of science into the K-12 science education and science teacher training programs. The framework is based on a 'piecemeal' or stepwise approach to conceptual changes in scientific knowledge. The piecemeal approach distinguishes itself from the extant 'holistic' or hierarchical views of conceptual change being applied in science education programs by allowing separate processes of change to occur to theory, to methods, and to aims. A strength of the piecemeal approach is that it more accurately depicts, epistemologically and psychologically, the dynamics of conceptual change.

Adopting a piecemeal developmental perspective of conceptual change would offer quite different criteria for deciding what to teach and how to teach. Empowering teachers with appropriate and internally consistent philosophical and psychological models for the selection and the sequencing of instructional tasks would assist them with describing and prescribing effective meaningful learning strategies. A developmental model for the growth of scientific knowledge would also assist students with organizing the conceptual frameworks of science and achieving a state in which they are capable of assessing the degree of legitimate doubt associated with scientific knowledge claims.

One advantage of the piecemeal model of conceptual change is that it better explains the difficulty we as science educators experience when implementing conceptual change teaching methods. In brief, it seems we have underestimated what needs to be changed. Changing the learners' conception of the meaning of concepts may not, in and of itself, be sufficient for effecting a shift in commitment from one view or framework to another. There may also be a need to change learners' conceptions of the methods employed to gather evidence and the aims of science.

The piecemeal conceptual framework provides a sound basis for developing what is known in science but, and more importantly, it more accurately portrays how changes in scientific knowledge occur. It is from such an understanding of the procedures of change, as such change relates to the justification of evidence, observation, and theory from a developmental perspective, that teachers of science shall gain a perspective on how and what declarative and procedural knowledge ought to comprise the planning, implementation, and evaluation of the science curriculum.

THE IMPACT OF A NATIONAL STUDY ON THE POLICY AND PRACTICE OF SCIENCE TEACHING IN BRITISH COLUMBIA

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The Science Council of Canada recently completed a study of science teaching in Canada which examined the practice of science teaching, analyzed the curriculum materials used, and sampled public opinion through position papers and deliberative conferences. The wide distribution of the report and the attention that it has received nationally provides an opportunity to examine the links between research, policy making and curriculum practice such that we could learn more about the contexts and influences that provide improved curriculum practice. Thus, a study was undertaken to survey the major stakeholders to determine the influence the study and its reporting had had on changes in science teaching and policy making with regard to curriculum. The data sources included 350 teachers in two districts in British Columbia, one rural and one urban. In addition, superintendents, board chairmen, and science coordinators were also surveyed in all 56 districts in the province. Those in decision making positions in the Ministry and those who prepare teachers in Faculties of Education and selected science departments were also surveyed. The results were analyzed using a four stage model which included intentions, observations, indicators of success and subjective analysis. The authors drew on change and organizational theory as well as knowledge utilization to provide a more theoretical approach to examining the results. The survey indicated that the common perception that many changes were occurring at the school level was largely illusionary. However, teachers in some schools did report an increased emphasis in science. Most attributed the change to some initiative at the school or district level. Only one teacher in the sample of over 300 had heard of the Science Council of Canada report. At the level of the District and Ministry a very different perception was reported. Here, one gained the sense that many changes were occurring. They did not attribute these changes to the Science Council of Canada Report directly. What the report had been successful in doing, they reported, was to set a context for change in science education. The paper argues that the relationsip between research, policy and practice with regard to science curriculum in the province is restricted by the existence of two cultures, those inside the classroom and those on the outside. Those on the outside, such as Ministry and district policy makers and science educators, who are in the best position to help teachers, operate from a set of cultural perspectives that are not necessarily grounded in a reality of the classroom. Teachers operate with a very different cultural view. The links between the two are not strong, making the prospect of reform remote. The paper offers a series of recommendations for improving the links between research policy and practice.

THOSE WHO CAN BUT DON'T: TRENDS IN EDUCATING YOUNG WOMEN FOR CAREERS IN ENGINEERING IN SINGAPORE

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The study was an attempt to obtain baseline data concerning the educational choices that result in young Singaporean women opting for or against science and technology related careers. The various disciplines in engineering were targeted for specific study.

Approximately 500 women were surveyed by use of a questionnaire used in an earlier study in the U.K. by Keenan and Newton. Follow-up interviews were conducted with 20% of the respondents who were practicing engineers or who had qualified as engineers but who were not currently practicing their profession. The subjects were asked to reflect upon what had influenced their decision to study engineering, how they had been treated during their years of study, and the level of job satisfaction they were currently experiencing in their work. They were also asked to project their prospects for promotion and career advancement with their present employer.

The data revealed a variety of factors that influenced choice of engineering as a profession. The most commonly cited influence was the challenge presented by what were regarded as difficult school subjects, namely: mathematics, physics and chemistry. Many cited an aptitude and liking for mathematics but a disinclination to teach the subject as a reason for choosing engineering.

Over half of the women interviewed indicated that they never intended to practice as engineers. They were advised by family members and teachers that since engineering is a professional degree requiring four rather than the usual three years of study to obtain a bachelors degree, their opportunities in the job market would be increased and their starting pay would be higher. Some compromised by entering academia to teach their discipline without obtaining any work experience whatsoever. Others continued their studies and obtained an MBA. These individuals are currently working in an occupation to which a bachelor's degree in engineering is marginal to their daily work.

It was clear from the study that as far as the situation in Singapore is concerned, there has been an over-investment in engineering education for women. Many of the young women who found a challenge in studying engineering and completed their studies are not practicing as engineers in numbers consistent with their representation in each graduating class.

Conditions in the workplace play a large part in discouraging women from practicing their profession once they have become qualified. It was concluded that in order for women engineers to be successfully absorbed into the workplace culture, there must be a concerted effort to arrive at a mutual adaptation both by the women concerned and by the workplace culture.

CHARACTERISTICS OF FEMALE ADVANCED SCIENCE STUDENTS - SECOND IEA SCIENCE STUDY

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Girls are given hints throughout their lives that science is a masculine subject. Once they reach upper secondary school, where science courses are generally electives, girls tend to opt out. The one content area where girls can be found, however, even in advanced science courses, is biology. In 1986, the Second IEA Science Study collected data from science students across the nation. This was part of a larger international study conducted by the International Association for the Evaluation of Educational Achievement (IEA). Not only were students given achievement tests, but they were also asked to respond to a number of questions regarding their home and school life and their attitudes toward science. This paper describes the characteristics of female students who have elected to take an advanced physics course in high school. It compares them with both male advanced physics students and with females who have elected to study an advanced science in the more "feminine" area of biology. In general, girls in physics are more like boys in physics than they are like girls in biology. Physics students appear to come from a slightly higher SES. They own calculators, use computers, and have taken more math courses than have biology students. More girls and boys in physics claim to be "A" students, intend to study science in college, expect to go to graduate school, and plan to use science in their careers. These physics students also reported finding science more interesting and enjoyable, and less difficult, than did the biology students. While girls said they spent more time on homework than did boys, physics students reported spending more time on homework than did students in biology. The major differences between boys and girls in both biology and physics was that boys tended to have more negative attitudes toward school in general, and surprisingly, that boys more often felt that science was responsible for much of the anxiety and problems in the world today.

DEVELOPMENT OF A THEORETICAL BASIS FOR GENDER DIFFERENCES IN INTEREST LEVELS AND RETENTION RATES IN SCIENCE

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A series of paradigm-based research projects first identified factors affecting the enrollment levels and retention patterns of girls in upper division science classes (chemistry and physics). A case study approach was combined with personal, social, and career measures to identify effective teaching strategies and behaviors. Significant results indicated that specific instructional behaviors and materials were effective. The next step was to assess the feasibility of transferring the identified behaviors and the use of special instructional materials to another group of teachers. A field experiment involved rural schools and male biology teachers. The schools were equivalent on several socio-economic and population measures, and the teachers had comparable backgrounds and experiences.

The research design involved the test of two types of intervention programs: one was called "limited" intervention and required teacher request of materials or assistance; the other one was described as "full" intervention and scheduled a full program of materials, role models, and field trips as well as demonstrated effective teaching strategies into the teacher's class. The third school served as a control setting.

After a semester's intervention, students were tested on a variety of attitudinal, career interest, and science experience measures. In addition, students were asked to Draw-a-Scientist (DAST). Also, present achievement and future enrollment data were collected.

Results were varied and showed the relationship between grading policies and positive attitudes. However, the results of both the DAST test and enrollment data indicated a positive effect of the intervention strategies.

The basic research question, "Can teaching behaviors including the effective use of specific materials be transferred from one group of teachers to another?", was answered positively. However, the efficacy of the specific strategies involved in the study was questioned. Therefore, a third research project is attempting to compare the effectiveness of affective intervention (use of role models, inclusion of career information) with the effectiveness of cognitive intervention (skills enhancement, visual-spatial development, technique and experiment practice).

WOMEN SCIENTISTS' CONSTRUCTION OF KNOWLEDGE AND LEARNING IN SCIENCE

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Scientific fields will require a larger pool of qualified scientists in the future. The percentages of minorities and women in science must increase in order to make up that need. Although a number of programs have been implemented in schools and communities to encourage participation of minorities and women in science and math, these efforts have not created the critical mass sufficient to re-norm science practice so that it is attractive to this underrepresented portion of the population.

Attitudes and beliefs about women's ability to do science have discouraged many women. There is an increased awareness of those beliefs and of discrimination, but examining the assumptions underlying these attitudes and changing them is a slow process. A related and more subtle belief is about the nature of scientific knowledge and how science must be learned.

Women scientists, talking about how they learned science and how they do scientific research, reveal their conceptions of scientific knowledge construction and science learning. Conceptual learning that is meaningful and affective occurs as women scientists engage in research activities. Recognition of features of these learning experiences may be instrumental in encouraging science students toward more powerful conceptual learning and knowledge construction in science.

DEVELOPMENT, TRIAL IMPLEMENTATION, AND EVALUATION OF AN INTERPRETIVE INTERACTIVE MEDIA PROGRAM FOR A NATURAL HISTORY EXHIBIT

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Previous evaluation studies of visitors' experiences in the Ocean Diorama, Royal British Columbia Museum, and studies of the effectiveness of naturalist/interpreters in the context of the Ocean Diorama suggested that an interactive media program modeled along the lines of a naturalist/interpreter expert system might be used to enhance interaction of museum visitors with the objects of natural history exhibits. With enhanced levels of interaction, visitors might be expected to experience both improved learning from the Ocean Diorama and a greater appreciation of their experiences in the exhibit. This paper describes the development, trial implementation, and evaluation of an interactive program specifically designed to explore possible implications of interpretive interactive media displays.

A cost analysis of interactive systems suggested that HyperCard, a new software application for Apple Macintosh computers, to be an economical interactive media. HyperCard appeared to possess features appropriate to the problem, including low cost and a high level of interactivity made possible by its abilities to quickly manipulate graphic, textual, and audio information. HyperCard also had the added benefits of being relatively easy to learn and highly adaptable as a graphic display environment.

The development phase of this project utilized a naturalistic research and development model. The pre-design phase involved interviewing and observing three experienced nature interpreters interacting with visitors to the Ocean Diorama in an attempt to describe an expert system. Based on these data and a survey of the museums literature eight design features for the interactive system were defined.

The design phase attempted to incorporate these design features and model the objectives and interactions exhibited by the expert nature interpreters. The HyperCard programs allow the integrated use of sound, visuals and textual materials with the objects of the Ocean Diorama. The Macintosh "mouse" and the active areas on screen provided a simple access operation to rather complex information for the users.

The Explore the Shore series of programs is a total of seven HyperCard stacks developed specifically for this project. Each stack contained a variety of sound, visual and textual materials.

An evaluation of Explore the Shore and the microcomputer systems suggested that such interactive media systems have potential to attract and hold museum visitors to natural history exhibits and increase learning without decreasing the affective growth produced by such exhibits.

A COMPARATIVE EVALUATION OF INQUIRY ACTIVITIES IN HIGH SCHOOL BIOLOGY CURRICULA OF KOREA AND THE UNITED STATES

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Many research data support the opinion that there has been inadequate effort to develop satisfactory inquiry activities to be incorporated in science curricula. And the systematic evaluation of the inquiry activities in science curricula has been far outpaced by the development and implementation of science curricula which may have some internal deficiencies. It is the special concern of the researcher to find out any deficiency in inquiry activities in high school biology curricula of Korea and the United States, as well as possible differences and similarities between those of the two countries.

Two widely used biology textbooks in the United States and two in Korea were selected, and the inquiry activities in the textbooks were evaluated using an instrument, Scientific Inquiry Evaluation Inventory (SIEI). It appears that inquiry activities in high school biology curricula of Korea and the United States have some intrinsic deficiencies as evaluated by SIEI. The main findings of this study can be summarized as follows.

(1) The inquiry activities mainly emphasize basic or low level science process skills, and this is more serious in Korean biology curricula.
(2) The inquiry activities are highly structured like a cookbook, thus limiting the opportunities to think creatively.
(3) The inquiry activities have competitive structures, which may act as a barrier against optimizing students' achievement of inquiry skills.
(4) There is remarkable difference in the amount of time allotted to labs as measured by Inquiry Index of SIEI between Korean and American high school biology curricula.

According to the results of this study, it is highly recommended to make more effort to improve the content and organization of inquiry activities in high school biology curricula of both Korea and the United States.

IMPACT OF LARGE-SCALE TESTING ON SECONDARY SCHOOL SCIENCE EDUCATION

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The pros and cons of large-scale testing have been argued for decades. That some kind of assessment of student progress is both necessary and desirable is generally accepted, but just who should undertake it remains a contentious point. At the heart of the argument for external examinations lies the implicit assumption that the classroom teacher cannot be left solely responsible to assess pupils. For purposes of accountability external testing seemed to be the answer. Views such as these were behind the movement that led to the National Assessment of Educational Progress in the United States in the early 70's and the British Columbia Learning Assessment Program in the Province of British Columbia in 1976.

Concerns about the practice of large scale testing have been expressed by a growing number of science teachers in British Columbia who argue that the quality of science education has deteriorated; that students are being forced to master "facts" to the detriment of learning principles. Others support the contention that testing is forcing unintended changes in the curriculum as teachers are encouraged to "teach to the test." If such allegations are indeed true, then large-scale testing is creating serious problems in our schools. But the testimony and reports on which these allegations are made are largely unsubstantiated. What is required is a systematic examination of the effects of large-scale testing on classroom teaching.

This study is designed to examine the impact of large-scale testing in science teaching at the district, school and classroom levels. As a first step in conducting this study, the research team undertook a review of the literature designed to examine the background to the testing movement, the arguments for and against testing, and to identify the issues that can guide further research. The purpose of this paper is to report on this first stage of this research, the literature review.

The results of the review showed a curious dichotomy in the literature. On the one hand, one finds the critics who attack large scale testing on the grounds that it reduces the authority of the science teacher, centralizes curriculum and augurs against the concept of the educated person. On the other hand, those supporting testing seem to take it as a given and devote their efforts to improving the technology. The paper identifies several issues that require attention in further research.

A STUDY OF THE IMPLEMENTATION OF THE TEXAS ELEMENTARY SCIENCE PROGRAM

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Texas' response to the educational reform movement was to mandate a state-wide curriculum known as the essential elements. However, provisions for managing and financing implementation were not made. Individual school districts were left to meet the legislation in whatever way they could.

The purpose of this study was to assess the concerns of Texas elementary science teachers regarding their use of the mandated activity-based, process science program as reflected in their responses to the Stages of Concerns Questionnaire as developed by Hall and others.

A random sample of 400 elementary science teachers was drawn from the data base of the Texas Education Agency. Address labels were provided and the Stages of Concerns Questionnaire and demographic form were mailed in the first week of April, 1988. By the end of May, 1988, 41% of the questionnaires had been returned. This return rate suggests a cautious interpretation of the outcomes.

The results showed that four years after the new elementary science program was initiated, K-6 teachers had a "non-user" profile, with most intense personal concerns, and least intense consequence concerns. This, in combination with a "tail up" on refocusing concerns, suggests a general apprehension about the mandated science curriculum. Partition of the data by grade levels and by years experience teaching elementary science revealed more teacher apprehension about the program in grades K, 1, 2, 5, and 6, and for teachers with more than 20 years of experience.

The profiles have all the characteristics that one would expect for a program that was mandated from the top down and for which teachers have not received the training, materials and support they feel they need. At the state level, a comprehensive effort should be planned to respond to these concerns. Local districts would do well to do a careful study of the concerns of their teachers about this mandated program and plan intervention strategies to respond to local teacher concerns.

Research Seminar

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This research seminar is designed to provide NARST members with an opportunity for further discussion with John Bransford relative to his general session topic, Designing Invitations to Thinking.

THE MATTER AND MOLECULES PROJECT: CURRICULUM DEVELOPMENT BASED ON CONCEPTUAL CHANGE RESEARCH

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This paper describes the development of a sixth grade Matter and Molecules unit using a new curriculum development model based on conceptual change research, the field testing of this unit in fifteen classrooms, and the field testing results. In the paper, the development process and the resulting unit are contrasted with the unit's commercial predecessor, the "Models of Matter" unit in the Houghton Mifflin Science sixth grade text.

The development process was based on an extensive program of research on student conceptions and classroom teaching using pre-clinical interviews, pretests, classroom observations, journals by collaborating teachers, post-clinical interviews, and posttests. The development procedures also included a careful content analysis, and extensive interaction with collaborating teachers who were part of the development team.

We argue that the procedures described in this paper constitute a workable alternative to present curriculum development procedures, and that the alternative procedures are superior in two respects. First, these procedures make use of the methods and findings of recent research on teaching and on students' scientific cognition. Second, posttest results and interviews with teachers indicate that the new unit was demonstrably superior to its commercial predecessor in terms of students' conceptual understanding and teachers' professional satisfaction.

MIDDLE SCHOOL TEACHERS' CONCEPTIONS OF HEAT AND TEMPERATURE: PERSONAL AND TEACHING KNOWLEDGE

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Research has shown that microcomputer-based laboratories (MBL) hold promise for helping students form more appropriate science concepts. However, the overall effectiveness of MBL will depend upon the teachers' understanding of how to use the new technology, their understanding of the science concepts, and their understanding of how to teach the concepts.

In this study, we examine middle school teachers' content knowledge of heat and temperature as well as their pedagogical content knowledge, knowledge of how to teach these concepts. We also examine the influence of a three week MBL workshop has on changing their understanding of heat and temperature concepts and their knowledge of how to teach these concepts.

Twenty-two middle school science teachers from three different counties, representing 13 different schools, took part in a three week workshop that focused on using MBL to teach heat and temperature concepts. Throughout the workshop teachers performed a variety of laboratory activities related to heat and temperature using MBL. The laboratory activities required teachers to make a prediction and then perform a laboratory activity using MBL to test out their prediction.

Pre/posttests and semi-structured interviews probed teachers' understandings of heat and temperature concepts. In addition, the semi-structured interviews probed teachers' knowledge of how to teach heat and temperature concepts. All twenty-two teachers answered a concept pretest on the first day and a concept posttest on the last day of the workshop. The pre/posttest focused on graphing skills, concept understanding, and graphing and concept skill integration. Twelve of the teachers were randomly selected to take part in the interview portion. Initial interviews were conducted the first week of the workshop and follow-up interviews were conducted at the beginning of the 1988-1989 school year. Interviews lasted between 20 and 40 minutes depending on the responses the teachers made.

Tentative analysis of the data indicates that, prior to the MBL workshop, many of the middle school teachers held alternative concepts related to heat and temperature. The responses given on the semi-structured interview indicate that they created elaborate explanations to support even their alternative conceptions. In addition, many of the teachers held weak ideas on how to teach heat and temperature concepts. The posttest data also indicate that modest gains were made as the result of the MBL workshop; however, many teachers held onto alternative concepts or incorporated their knowledge to form new hybrid alternative conceptions. Even after the workshop, many of the teachers still held weak ideas on how to teach heat and temperature.

The results reported appear very consistent with the conceptual change literature and Shulman's work on pedagogical content knowledge. We strongly believe, and our work indicates, that to help teachers form appropriate scientific concepts, develop a deep conceptual understanding of how to teach science concepts, and use new technology in the science classroom requires careful work over a prolonged period.

MISCONCEPTIONS IN THE EARTH SCIENCES: A CROSS-AGE STUDY

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A questionnaire containing several possible earth and space science misconceptions was administered to 1213 students in a cross-age study in northwest Indiana. The sample included a mixture of white, black, and Hispanic participants who were either students in the 5th, 8th, or 11th grades, or were enrolled in local universities or a trade school. Each of the 18 multiple-choice questions on the instrument was written so that there was one scientifically acceptable answer, one or two suspected misconceptions, and one or two plausible distracters.

Common misconceptions were identified from distracters which were chosen at least twice as often as the least chosen distracter for a particular question. Primary misconceptions were defined as those common misconceptions which were chosen more often than the scientifically acceptable conception. Secondary misconceptions were defined as common misconceptions which were less popular than the scientifically acceptable conception. Functional misconceptions were defined as possible misconceptions, which if they exist, could seriously interfere with one's ability to function in society.

Data from this study have verified that misconceptions in the earth sciences are widespread. Six primary misconceptions were identified, as were fourteen secondary misconceptions. One functional misconception is suspected to be common among some subgroups.

Misconceptions were found with great regularity in both males and females, in all racial groups, among urban and suburban students, and across all five educational levels studied. Students who had taken earth science classes had slightly fewer misconceptions than those who had not. However, there were several questions for which those who had not taken earth science did better than those who had. Although significant (alpha = .01) differences were found across genders, races, educational levels, and locations, the differences in misconceptions means were smaller than the differences in scientific conception means.

CORRELATES OF STUDENT PERFORMANCE IN THE SCIENCE OLYMPIAD

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The Test of Integrated Process Skills (TIPS) was administered to 457 students in grades 9-12 who were registering to participate in a regional Science Olympiad. This test was designed to measure competency in the process skills of (1) stating and revising hypotheses, (2) identifying and controlling variables, (3) operationally defining critical terms, (4) graphing and interpreting data, and (5) designing an experiment. Each student's score on the test was correlated with subsequent performance in one or more of the 22 Olympiad events. The Olympiad was conducted on a university campus in February, 1988, under the rules of Division C of the National Science Olympiad Steering Committee. Of the 667 students who participated in the Olympiad, 404 had usable scores on the Test of Integrated Process Skills.

Five of the 22 events produced Spearman rank-order correlations with TIPS scores which were significant at the .01 level. These events were Bio-Process Lab, Designer Genes, Measurement Lab, Periodic Table Quiz and Science Bowl. An additional three events (A is for Anatomy, Topographic Map Reading and The Pentathlon) produced correlations at the .05 level of significance. Descriptions of scoring criteria for events which produced significant correlations provide limited support for the predictive validity of the TIPS in forecasting student performance in skills-based science competitions such as the Olympiad.

Additional student demographic data were collected. Results indicate that type of school, number of previous Olympiads attended, and number of science courses completed produce significant correlations with rankings in some Olympiad events. No significant correlations were found between age, race, grade level, and student enrollment in school with rankings in any Olympiad events.

PROFILE, ANATOMY, AND EFFECTIVENESS OF COLLEGE SCIENCE DISTANCE TEACHING AS COMPARED TO A TRADITIONAL MODE COLLEGE SCIENCE COURSE

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In recent times, few technological applications like television have had such an impact upon all aspects of life. For students it has readily changed their learning styles and even their abilities. The statistics speak for themselves. The Carnegie Commission reported that sixty-four percent of Americans rely on television as their principal source of news. The average high school graduate has spent nearly 50 percent more time in front of the television set than in the classroom. Television's virtue is that it can excite, arouse, create an emotional climate and a sense of mission. In the sciences, this type of medium may be worthwhile to not only increase the numbers of science majors but also to educate the general public and achieve some measure of scientific literacy.

The purpose of this study was to describe the types of college students enrolled in a college science telecourse and to assess its effectiveness in terms of achievement, attitude, and student retention as compared to a traditional college science course.

The telecourse, "Project Universe," used in this study was designed to have not only a televised component but also an accompanying textbook and study guide. According to Zigerell, the term telecourse is a recent one intended to distinguish from what has been loosely called "TV courses" or "televised courses." The televised course is not just a sequence of instructional television programs but a distinctive multisensory presentational medium taking full advantage of all possibilities for on-site filming, creative editing, and studio enhancement. The study guide outlined activities and objectives for the students. Students were required to attend an on-campus orientation during or before the first week of broadcasts. Optional review sessions were also provided for all students. Students could also confer with the instructor via the telephone. A newsletter was also sent to each student four times during the semester. No laboratory experiences were required or provided. The traditional course followed the on-campus lecture mode using the same text and also having no lab experiences.

Telecourse students were found to be different from their on-campus counterparts. The successful telecourse student is a mature adult, credentials-minded, career-oriented, and highly motivated. Attrition rates were higher in the telecourse. Students did not drop due to dissatisfaction with telecourses, but rather due to other outside pressures or reluctance to learn independently.

Students enrolled in the telecourse achieved as well as their counterparts in the traditional class. Most students indicated that they would take another telecourse in the future.

The overall results point toward the value of learning science in this mode. For some students, telecourses may be their only access to adult learning.

TAKE HOME SCIENCE KITS FOR FAMILIES

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A major reason for the lack of scientific and technological literacy in this country is the lack of emphasis on high quality science education at the elementary school level. The National Science Board Commission on PreCollege Education in Mathematics and Science states in its report that formal study of science must be reinforced by a wide range of activities outside the school. Further the Commission report states that few children are exposed to stimulating out-of-school experiences. The Task Force on Education for Economic Growth recommends that special efforts be made to encourage women and minority students in science. Learning in the home appears to be an excellent way to enhance elementary school science programs. Students who study with their parents or whose parents are involved in school activities achieve more in school. This paper describes and presents evaluation data for a program that encourages elementary school students and their parents to study science topics in a hands-on, inquiry fashion in their own homes. The students are given the opportunity to take home unique, inexpensive science kits that contain all of the material and instructions necessary to conduct a series of experiments about a particular science topic, e.g., Critter Watch and Bubble Fun. Parents and students in first and third grade experimental and control group classes were pre and post tested. The analyses of the data indicate that the program is viewed very positively by both the students and their parents, that there are gender and grade level differences in the students, and that the program seems to be most effective for girls, a group at-risk for continuing on in science.

T-ZONE, TARGET STUDENTS AND SCIENCE CLASSROOM INTERACTIONS

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This study investigated the seating patterns of target students in science classrooms to see if there was an action zone or t-zone present. Fifty-six physical science and chemistry classes were observed using the Brophy-Good Teacher-Child Dyadic Observation System. Target students were identified and their interactions were compared to non-target students. Target student interactions for direct questions and student-initiated interactions were analyzed to ascertain whether the teacher or the student determined target student status.

Results indicated that no t-shaped action zone was present in the classes involved. Target students dominated class interactions and received more direct questions, teacher afforded conversation and sustaining feedback. Nearly one-third of all students observed in the study did not interact at all and were silent.

Informal Discussion

"AN HOUR WITH..."

The President

of the

National Association for
Research in Science Teaching

Patricia E. Blosser

This session provides NARST members with an opportunity to talk informally with the NARST president about matters concerning the organization.

SCIENCE ACHIEVEMENT OF COSTA RICAN SIXTH-GRADE STUDENTS AND ITS RELATIONSHIP WITH SELECTED VARIABLES

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This study had three purposes. First, to develop and validate a criterion-referenced test to measure science knowledge of students who finished the second cycle of the Basic General Education (6th grade). Second, to assess the performance of the entire Costa Rican population of sixth graders and, third, to analyze the results according to some selected variables.

The test developed in this study can be classified as a criterion-referenced test, because it possesses two different characteristics of that kind of measurement instrument: it measures a very well defined and specific content domain, and the results are interpreted in teams of the mastery of that content domain.

Experienced elementary science supervisors and college science educators chose the 18 more important science skills. These were translated into behavioral objectives and into amplified objectives. Teachers were paid to write multiple-choice items, twelve per objective. An item-objective congruency index was calculated. These procedures gave supportive evidence of the curricular and content validity of the test. For each item, the Brennan discrimination index was calculated, and all of them were administered in a pilot test to a sample of sixth graders. These two procedures permitted selection of the best items for both tests. In each test, 16 objectives were measured by three items each. Fourteen objectives were common to both tests.

The reliability of the tests were calculated according to the Kuder-Richardson procedure. The values obtained were 0.83 and 0.85.

The tests were administered to the entire population of Costa Rican sixth graders. A total of 34862 usable answer sheets were collected.

At the national level, the mean per objective varied from a minimum of 0.97 (objective 16) to a maximum of 2.85 (objective 18). Ten of the eighteen objectives had means over two (the cut-off score). The percentage of students mastering the objective ranged from 5% to 88%. Seven out of the 18 objectives were mastered by more than 50% of the students.

Looking at the data by region, the same seven objectives were mastered by 50% of more of the students in 14 out of the 17 regions. The same results are obtained comparing the school by size.

Achievement in the private schools is better than in the public schools, 10 objectives were mastered by 50% or more of the students in the private sector compared with seven in the public schools. The urban schools did not differ from the rural schools in the number of objectives mastered by 50% or more of the students.

Analyzing the means per objective, in general, it can be concluded that the larger the school, the higher the means. The same results hold when the urban schools are compared with the rural ones.

TEACHING ELEMENTARY CHILDREN AN ANALOGY OPERATIONALIZES THEIR DESCRIPTIONS OF THE STATES OF WATER

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This paper reports a descriptive study of 24 elementary children who were instructed in the use of a sugar cube analogy for describing the states of water. The purpose of the study was to see if children could show an understanding of the analogy by employing it their descriptions of state transitions in water. The structure-mapping theory of analogies of Gentner was used to design instruction for elementary school children, grades 3-5. Children's responses to open-ended questions about the states of water shifted from vague references to inappropriate scientific principles to operational expressions which suggested specific manipulations and observations. The children were given a survey presenting common misconceptions about the relationship between the states of matter along with the "particle dynamic" view. Although the "particle dynamic" view was not universally accepted, there was a clear shift from a transmutation view toward a particle concept. The results of this study suggest that careful instruction in the use of analogies may aid communication of ideas between students and teachers as well as helping children understand the implications of their own ideas.

THE RELATIONSHIPS OF ACHIEVEMENT, INSTRUCTION, AND FAMILY BACKGROUND TO ELEMENTARY SCHOOL SCIENCE ACHIEVEMENT IN THE REPUBLIC OF CHINA

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The purpose of this study was to identify strong predictors of science achievement for grades three to five in the Republic of China. There were 38 schools (2950 students) involved. Selected variables included:
(1) students' background variables including students' parental education

and occupation, students' age and sex; (2) academic variables including Chinese, mathematics and science achievement; (3) school size; and (4) teacher inservice training.

Data were analyzed through frequency, correlation and multiple regression. Stepwise multiple regression was run separately for each semester by using students' background, scholastic ability (Chinese and mathematics achievement), and previous science achievement as independent variables; the science score was the dependent variable.

Results indicated selected variables explained an average of 50 percent of the variance of science achievement. Home background accounted for nine to thirteen percent of the variance. Within the home background category, fathers' educational level was the strongest predictor and accounted for about four percent of the explained variance. Previous science scores accounted for ten to 45 percent of the variance, with a mean of 32 percent. When home background and scholastic ability were removed, previous science scores accounted for ten to 15 percent of the variance. Mathematics achievement accounted for a mean of 32 percent of the explained variance (20 to 30 percent of the variance when home background was removed).

Inservice teacher training, school size, and students' sex each individually accounted for less than one percent of the variance of science achievement.

Further studies related to the effectiveness of the inservice teacher training, congruence of curriculum objectives and test items, and characteristics of effective schools are recommended.

HOW DO CHILDREN DEVELOP SCIENCE KNOWLEDGE? AN INTERIM REPORT OF TRENDS FROM A LONGITUDINAL STUDY

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How do children develop science knowledge? This symposium seeks to answer that question from a longitudinal data base (kindergarten through second grade) of approximately 325 children from three school districts. The objectives of this program of research are to present a heuristic model of children's science knowledge development that includes measures of entering general ability, home background, instructional materials, teachers' management styles, home support for science knowledge, and independent reading. These data have been analyzed using LISREL. The results of

structural models for the kindergarten level show entering ability to be the single best predictor of student performance by the end of kindergarten. At the first grade level, teachers' use of science textbooks was negatively related to student performance while entering ability and teachers' uses of sustained feedback and the children's home backgrounds were significant predictors of students' performances in science at the end of the year. The results of the final structural model at the second grade level continue to show entering ability and home background to be significantly related to student performance. In addition, time spent in science instruction and teachers' uses of interactions with students that have them apply concepts were also significant. Science textbook usage and the number of science content domains covered had a negative relationship to end-of-year performance in science in second grade.

Symposium

A CANDID DISCUSSION ON ENHANCING OUR JOURNAL

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RELATIONSHIPS AMONG INTEGRATED SCIENCE PROCESS SKILL ACHIEVEMENT, LOGICAL THINKING ABILITIES, AND ACADEMIC SCIENCE ACHIEVEMENT OF TENTH GRADE PUBLIC SCHOOL STUDENTS IN TAIPEI, TAIWAN, REPUBLIC OF CHINA

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The purposes of this study are: (1) to identify the level of science process skill achievement and logical thinking ability of senior high students in Taipei public schools across two factors: gender and levels of entrance examination achievement, (2) to assess the relationship between science process skill achievement and logical thinking abilities and to determine if they are valid predictors of students' academic science achievement.

Six hundred thirty-five tenth grade students were classified into three levels -- high (N = 206, Male = 104, Female = 102), average (N = 231, Male = 114, Female = 117), and low (N = 198, Male = 105, Female = 93) according to the cut-off scores established by the 1986 entrance examination for Taipei senior high schools. The Test of Integrated Process Skills II (TIPS II) and the Group Assessment of Logical Thinking (GALT) were used to measure students' science process skills and logical thinking abilities performance. A science summative test was used to measure students' current (1986-1987) achievement in four science areas: Biology, Earth Science, Physics, and Chemistry. Analysis of variance, simple correlation analysis, general linear model, and factor analysis were used to analyze data.

The results showed that (1) there was significant but moderate correlation coefficient between integrated science process skills and logical thinking abilities, $r = .37$ ($p < .0001$); (2) there were significant gender differences in science process skill achievement, males outperformed females; (3) neither TIPS II nor GALT were effective predictors of individual academic science achievement.

Education in Taiwan has its own characteristics and also its own problems. However, integrating Western educational and psychological theories, such as the science process approach and Piaget's theory of cognitive development, into the science curriculum is imperative if Taiwan students are to contribute successfully to the cultural and intellectual development of society.

MIDDLE SCHOOL STUDENTS' PERCEPTIONS OF FACTORS FACILITATING LEARNING SCIENCE

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The purpose of this study was to explore what factors middle school students perceived facilitated their learning science.

Florida's Educational Reform Act of 1983 funded programs providing the states' precollege students with summer learning opportunities in science, mathematics, and computers. The programs were intended to encourage the development of creative approaches to the teaching of these disciplines.

Under this program, between 50 and 60 high achieving middle school students were in residence on the University of South Florida campus for 12 consecutive days of study in the World of Water program. There were two sessions per summer for the past five years totaling 572 participants.

Eight specially trained teachers were in residence with the students. Between 50 and 70 experts from the university, government, and business/industry interacted with the students each year in an experimental science/technology/society program.

An assignment toward the close of the program had students reflect on their experiences in residence at the university and write an essay comparing learning in the World of Water program to learning in their schools. These essays were the basis of this study.

This was a qualitative study using a discursive approach to emergent design generating grounded theory. Document review, participant observation, and open ended interviews were used to gather and triangulate data in five phases.

In phase one, essays were put in groups by year, numbered, and read in chronological order by yearly groups beginning with those generated in 1984. Students' statements identifying things which were of importance to them were extracted. Potential relationships among the statements were sought to identify categories and generate hypotheses.

In phase two, the researchers were participant observers in the two 1988 program sessions (totaling 112 students) looking for behavioral evidence for what students said was occurring and was important to them.

In phase three, the 1988 students and individual staff members were interviewed during the program using open ended questions derived from and reflecting the categories and emerging hypotheses.

In phase four, open ended group interviews of staff were conducted during the staff debriefing week at the close of the 1988 second session.

In phase five, the staff and the researchers explored implications of the findings for enhancing post baccalaureate education of middle school science teachers.

Some of the factors middle school students in this study perceived facilitated their learning science follow: 1) trusting the individuals in their learning environment including adults and students, 2) having close personal friends who shared their interest in learning, 3) experiencing a sense of self reliance, 4) establishing networks, 5) interacting with peers and adults, 6) experiencing the situations about which they were learning, 7) using inductive reasoning to generate new knowledge, 8) being active learners, 9) live presentations by professional experts, 10) hands-on learning, and 11) interdisciplinary approaches to problem solving.

The preceding information was used to generate a series of hypotheses which were woven together into a theoretical model suggesting ways to combine a variety of approaches to curricula, instructional designs, delivery modes, and teachers' behaviors that could help middle school teachers build factors that students said facilitated their learning of science into classes.

RELATIONSHIPS AMONG COGNITIVE STYLE, FORMAL REASONING ABILITY, PSYCHOSOCIAL ENVIRONMENT, ROBUSTNESS, AND COGNITIVE AND AFFECTIVE OUTCOMES IN EIGHTH AND NINTH GRADE SCIENCE CLASSROOMS

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The major purpose of this exploratory study was to examine the relationships among classroom environmental variables, student attributes, and cognitive and affective outcomes. The specific classroom environmental variables investigated were psychosocial climate and robustness, and the student characteristics were cognitive style (field independence/dependence) and formal reasoning ability. Student outcome variables were knowledge and understanding of selected physical science concepts and principles, and attitudes toward physical science classes. These variables were selected for examination because they all have been shown to be significantly correlated with student achievement.

This investigation was part of a pilot study designed to explore the effects of using student predictions about selected science concepts as a basis for teaching strategies which might help them restructure their knowledge and misconceptions. The subjects were 60 eighth-grade students in two intact classes taught by one teacher in one school and 98 ninth-grade students in three intact classes taught by one teacher in another school. Students were administered pre- and posttests of knowledge and understanding of selected science concepts, pre- and posttests on attitudes toward science classes, and pretests on cognitive style and formal reasoning ability. In this phase of the study, students were administered measures of two learning environment variables, psychosocial climate and robustness, and relationships among all of the constructs were examined.

Nine or more of 15 possible factors of the LEI were found for seven of the eight robustness constructs investigated, and six significant factors were found for the remaining construct. The consistency of the patterns of significant factors was striking.

Cognitive style and formal reasoning were not significantly related to the psychosocial climate of the learning environments but they were significantly related to each other ($r = 0.42$) and to the physical science posttest. The correlations for cognitive style and formal reasoning and the posttest were 0.38 and 0.34 respectively; neither of the variables correlated with post-attitudes.

A Maximum R-Square multiple regression procedure indicated that the best three-variable model for the physical science posttest scores accounted for 40 percent of the variance in the dependent variable when pretest scores, cognitive style, and Material Environment were entered in the analysis. The best three-variable model for the posttest attitude scores accounted for 46 percent of the variance and was represented by two robustness concepts, My Science Teacher Is and Science Is and the LEI subscale, Formality.

CONCEPTUAL CHANGE STRATEGIES AND COOPERATIVE GROUP WORK IN CHEMISTRY: AN EXPERIMENT

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Difficulties in implementing instructional strategies for overcoming student misconceptions involve teachers' remembering individual students' misconceptions and supplying many examples of correct concepts.

This study examines a method of conceptual change in which students are more actively involved in their own change process. Small cooperative groups are used to engage students in tasks aimed at eliciting their misconceptions so that they can be discussed in contrast to correct concepts taught in direct instruction.

Community college students' understanding of the laws of conservation of matter and energy and the particulate nature of matter was categorized by testing. Transcriptions of interaction during small group sessions provided means of examining student verbalizations in light of the conditions posited as part of the conceptual change process and other behaviors associated with positive group effects. Two instructors each taught one treatment and one control group. Thirty-five treatment students received direct instruction for five class periods, then worked in small heterogeneous groups on tasks designed to promote conceptual change. Tasks consisted of explaining responses to teacher generated questions and discussing student concept maps of course content. Twenty-seven control students had the same instruction, but received demonstrations in lieu of small group work. The sequences were repeated five times over the semester.

Chi-square analysis of pretests indicated groups were initially equivalent with regard to proportion of students with misconceptions and that treatment students had a significantly ($p < .05$) lower proportion of misconceptions on posttests for four of the five target concepts. Treatment students had a higher percentage of correct concepts than control students on all target concepts.

Student discussion was quantified into frequencies of behaviors suggestive of promoting or impeding conceptual change. Students who did not undergo any concept change had a higher frequency of verbal behavior suggestive of impeding conceptual change than students who had undergone a change in concept category. Four students who gave evidence of all four conceptual change conditions did undergo change and each had at least one correct concept on the posttest.

Qualitative analysis of group discussion indicated three influential factors: (1) some students had flawed understanding of the concepts of "create" and "destroy" that interfered with the "intelligibility" condition for conceptual change. The term "empty space" was also incorrectly used. (2) Student views concerning school work and science learning stood in the way of productive discussion. Students saw the focus of their task as finishing the assignment and their product had to please the instructor rather than provide plausibility for themselves. (3) Poor group leaders negatively affected conceptual change by rushing other group members through questions and being indifferent to directions for turn taking.

Study outcomes indicate the viability of the small cooperative group environment for engaging community college students in tasks aimed at overcoming their misconceptions of some important concepts in chemistry. The findings also provide some suggestions for guiding students in group work and in planning direct instruction to foster desired learning goals.

A STUDY OF CONCEPTUAL CHANGE IN JUNIOR HIGH SCHOOL STUDENTS DURING INSTRUCTION ABOUT THE CONCEPT OF BURNING

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The two main purposes for this study were to (1) investigate the nature of students' understandings about burning, and (2) describe the process of conceptual change during teaching about the concept burning.

Naturalistic data collecting strategies used in this study included participant observation, interviewing, and videotaping. Twenty eighth-grade students were interviewed using the "interview about event" technique, a variation of the Piagetian interview. The interviews were audiotaped, transcribed, and analyzed using analytic induction. The understandings identified in the analysis were used to design and teach an instructional unit about burning using conceptual change strategies. The lessons were videotaped, and the videotapes were transcribed and analyzed in conjuction with other data sources. Finally, daily interviews were conducted with three students following teaching. The daily interviews were audiotaped, transcribed, and analyzed to identify the changes in the students' understandings about burning across time.

Students' understandings about burning were found to be fragmented, inconsistent, and at variance with scientific knowledge. Additionally, successful conceptual change was identified and described in two of the students interviewed following instruction. The third student who took part in the post-instruction interviews did not show evidence of successful conceptual change.

IDENTIFYING AND CHANGING CHILDREN'S BELIEFS ABOUT CIRCULAR MOTION

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This study (a) identified and described conceptions about circular motion held by children (ages 7-9) and (b) explored the use of the Children's Learning in Science Project (CLIS) model for teaching these children about variables that affect circular motion via SCIS whirly-birds. The CLIS model accounts for student's conceptions in its suggested sequence. Two questions were explored: 1) what is the nature of children's beliefs about machines which display circular motion and variables which affect that motion? 2) do different kinds of introductory instructional activities produce differences in the degree of conceptual change for students about variables affecting circular motion? It was hypothesized that activities focusing on children's previous experiences would promote a greater degree of conceptual change than activities focusing directly on exploration of instructional materials (Karplus SCIS model).

Three classes of third-grade children (ages 7-9; 56 children in the sample) in one school were randomly assigned to two groups. The experimental group, Previous Experiences, received instruction in which orientation and elicitation phases dealt with the motion of merry-go-rounds, common playground equipment. The control group, Exploration, received instruction focusing initially on exploration of materials (whirly-birds). Total instructional time for each class was identical.

For both groups, students' ideas from class discussions about variables affecting the motion of these machines were recorded and transcribed. Both groups completed a six-question, multiple-choice measure to identify individual conceptions about three variables affecting the motion of these machines. An identical series of activities was conducted with both groups to systematically explore each of the variables. A set of summary demonstrations followed to reinforce the results of their experiments. One week later, both groups received a six-question, multiple-choice measure about the same three variables.

Analysis of written instruments and teacher notes for student dialogue prior to instruction for both groups supports the idea that children do have a variety of conceptions about variables that influence the motion of the machines used for this study. 1) Children generally believed that providing more force to start the machines into motion caused them to complete more rotations than those started on less force. 2) The majority of children believed that less mass on merry-go-rounds and whirly-birds caused them to complete more rotations. 3) The majority of children favored more rotations with machines that have masses closer to the axis of rotation.

Data from written instruments prior to and after instruction for both groups were analyzed for the proportion of children who chose an alternate conception prior to instruction and an accepted conception after instruction. Analysis of data revealed (1) more students in both groups retained their beliefs that a large force produced more rotations ($p < .05$); (2) the change in beliefs toward scientifically accepted views concerning the effect of amount of mass on the number of rotations was greater for students in the experimental group ($p < .05$); (3) the change in beliefs toward scientifically accepted views concerning the effect of relative distribution of mass on the number of rotations was greater in the experimental group and approached significance at $p < .05$ ($p = .07$). Results for a second variable, though not significant, were suggestive.

HELPING SCIENCE TEACHERS HELP SCIENCE TEACHERS: A STUDY OF CHANGE IN JUNIOR HIGH SCHOOL SCIENCE

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Recent reports about American schools have indicated the need for improvement of science and mathematics teaching and learning. One of the solutions advocated calls for extended professional roles for teachers of science and mathematics. These new roles would give teachers better preparation, support, and appreciation. The concept of Support Teacher was developed around three lines of force: teaching and learning of science and mathematics, improvement of classroom practice, and the use of recent research to direct efforts of improvement. A pilot implementation of this concept was started during 1987-1988 in four junior high schools in a small midwestern city. The program is a collaboration of school district, teachers' union, and Michigan State University. This study accompanied four science Support Teachers during the first part of the second year of the pilot implementation. The purpose was to trace and document the changes of these four teachers in classroom practice, conception of their role as teachers, and conceptions of science teaching. These changes were to be then related to the training for and implementation of the Support Teacher role. An interpretive methodology combining both qualitative and quantitative data were used. The data sources included: teaching style inventories, student achievement scores, classroom observations, interviews, fastwrites, fieldnotes, audiotapes, and videotapes. The main findings are that the four teachers have incorporated different forms of interaction with their students. A more clear preoccupation with student ideas and insights was apparent. The teachers' discourse about their classes also changed. They showed increased concern about how to engage all students instead of complaining about "problem students." The teachers conception of science teaching moved away from covering the material to being concerned with students' understanding of science. The results of this study confirm the possibility of extended roles for science teachers' and illustrate their benefits. A discussion of possible extensions/modifications of the concept of science Support Teacher implemented and studied is also offered.

THREE PERSPECTIVES ON THE PROBLEMS FACING THE SCIENCE TEACHING PROFESSION: A CROSS-NATION COMPARISON

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To acknowledge that teaching science in contemporary secondary schools is a complex and challenging task is most probably obvious and an understatement to those involved. Yet there is the suspicion that those concerned with different aspects of the profession of science education do not see the problems in the same way. If practicing science teachers, science supervisors, and those involved in the preparation of science teachers perceive the problems facing the profession differently, then proposed solutions will be slower and less effective.

Consequently, this paper reports research that investigates these groups' perceptions of the significant problems facing the profession. A two-state survey of Australian Public School science teachers, science supervisors (co-ordinators) and science teacher educators generated data on the priorities they gave previously-identified concerns about science teaching. These concerns were identified through previous studies (Australian and USA) and by a pilot study carried out prior to the major survey. The survey reports respondents' concerns with the areas of nature of science curriculum, leadership, budgets, time allocation, professional development, mixed ability classes, teachers' qualifications, staff continuity, image of science, science teacher preparation, science teaching research, public and parental attitudes, resource materials, evaluation, class size, isolation from research results.

The research revealed relevant information for those concerned with the training, operation, and support of secondary school science teachers. The consensus among the three groups on those matters rated of greatest concern gives a clear message to the decision-makers in those areas. Parallels are drawn with comparable data obtained in the USA and Canada.

Taking an extreme profile from those areas of greatest concern, the following picture could be painted. Science teachers, in wrestling with how to devise the most appropriate methods of dealing with classes of widely differing ability and motivation, find their efforts frustrated by a lack of system support for professional growth, by limited science budgets, and by a lack of time and expertise to adequately evaluate their efforts. Educational administrators, school principals and science teacher educators need to assemble as much evidence as possible on these kinds of concerns, so that they can devise a blueprint that will help science teachers prepare their students to live and work in an age increasingly dependent on science and technology.

COMPUTERS TO ENHANCE SCIENCE EDUCATION: AN INSERVICE DESIGNED TO FOSTER CLASSROOM IMPLEMENTATION

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This paper describes an inservice project designed by The Johns Hopkins University and the Baltimore City Public School System to help teachers acquire the skills necessary to effectively integrate computer technology into science instruction. From 1986 to 1988 the project was implemented in the large urban Baltimore school system with one hundred teachers who ranged in computer literacy from novice to experienced users. Components of the inservice design included teacher training, acquisition of hardware and software, development of model lessons, and the establishment of an extensive and diverse system to provide follow-up support. We are currently evaluating the nature and extent of the implementation of that training by close monitoring of both personal and classroom use of the computer by those trained. The project is supported by funds from the National Science Foundation and the Maryland State Board for Higher Education; hardware for project participants was provided by the Apple Foundation and the National Cristina Foundation.

Symposium: Problem Solving

ISSUES IN CURRENT PROBLEM-SOLVING RESEARCH

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One of the most fundamental goals of most classroom teachers is to enhance the thinking abilities - or more specifically the problem-solving skills - of students. Science has for some time been recognized as being an excellent vehicle with which to address this goal. Problem solving has therefore become one of the most actively studied topics for science educators today. The purpose of this symposium is to demonstrate some of the breadth of interests of this research, to acquaint NARST participants with some of the most recent findings, to provide a forum for individuals involved in the research to discuss critical issues, and to propose directions for the future of this research.

With one exception, all the presenters are members of NARST with active research programs in problem solving within the sciences. The other presenter is a anthropologist known for her work in the exploding new area of everyday cognition. Participants are drawn from the United States and Australia and represent a wide range of interests in problem solving. One of these individuals is a researcher associated with a school of medicine, one is a curriculum developer at BSCS, and the remaining individuals are affiliated with major research universities.

THE USE OF LINGUISTIC CONTENT ANALYSIS TO ASSESS THE IMAGE OF SCIENCE IN TEXTBOOKS

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Linguistic content analysis is a method of encoding textual data by categorizing key words and identifying the relationships among these words. Linguistic content analysis was used to assess the degree to which science was portrayed as a process of inquiry within a series of high school biology textbooks. The study was longitudinal, spanning the roughly thirty year time period from 1956 to 1985. A single textbook series was selected to avoid the possible introduction of extraneous variables due to different publishers. The series, Modern Biology, by Holt, Rinehart and Winston was selected for the study because it has a sequence of editions published both before and after the curriculum reform movements of the 1960s. It was hypothesized that these reform movements, which had as one of their themes the concept of showing science as a process of inquiry, would have an impact on the image of science portrayed in a popular series of high school biology textbooks. It was further hypothesized that the portrayal of science as a process of inquiry would be higher in chapters on genetics, a field of biology which has undergone a tremendous amount of growth in the last several decades, than in chapters containing highly descriptive material, such as the chapters on leaf structure and function.

A four-by-three factorial design was used, with four years of publication crossing three subject areas. The four years of publication, representing roughly ten-year time intervals, were 1956, 1965, 1977 and 1985. To represent contrasts in anticipated levels of inquiry, the introductory, genetic and leaf structure chapters were analyzed. Data were encoded with the aid of a computer program designed to improve the validity of linguistically encoded data. Logistic regression models were fit to the resulting categorical data. The results indicate that using the measure of inquiry developed for this study, the portrayal of science as a process of inquiry was lower in the 1956 edition, raised considerably in the 1965 and 1977 editions, and dropped heavily in the 1985 edition. The portrayal of science as a process of inquiry was highest in the introductory chapters, slightly lower in the genetics chapters, and very low in the leaf structure chapters. Level of inquiry was also highest at the beginning of chapters and at the beginning of paragraphs.

PROFILING ELEMENTARY TEXT-RELATED SCIENCE INSTRUCTIONAL MATERIALS

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The goals of this research were to: develop an instrument useful in analyzing the characteristics of teaching manuals used with grade 4-6 science textbooks; utilize both high and low inference questions in the instrument; develop three versions of the instrument, one for science education professionals, another for elementary classroom teachers and the third for their elementary students; and use samples from these three science education populations to profile science teacher's manuals.

Teaching manuals were analyzed because they are thought to be especially influential in elementary classrooms where reading is still not a fully developed skill. Since they are often the source for process-product/inquiry activities, teacher's manuals often play a central role in determining the quantity and quality of "hands-on" experiences students have. Both classroom teachers and science educators were polled to take advantage of their respective abilities to provide low and high inferential analyses of teaching materials. Classroom teachers who have just taught a chapter or unit using a teacher's manual are in an excellent position to quantify, tabulate and generally identify the characteristics of that manual. By looking through a teacher's manual, professional science educators can not easily identify and tabulate the attributes of a manual, but they <u>are</u> able to make complex judgements about its nature which may be beyond the sophistication of the typical teacher. Therefore, most of the items in the science educator's questionnaire require a high degree of inference while those asked of the classroom teacher are, for the most part, low inference items. The pupil perspective is also helpful in assessing the characteristics of a particular teacher's manual. If the manual encourages one sort of teacher activity and the students consistently report another, then that particular manual's ability to facilitate instructional methods would obviously be faulty.

The instruments were administered to 30 fourth grade teachers who use the Silver Burdett, Merrill or Scott Foresman text series in North Carolina, Minnesota, Texas, Missouri, New York, and Ohio. In addition, over 600 of their students completed the pupil instrument. After identifying the text chapters reported on by the teachers and pupils, science supervisors belonging to a professional science education organization were asked to profile the same materials. The results have been tabulated and reported as graphic profiles of each text series, along with tests for statistically significant differences.

The graphical comparisons of teacher responses show both similarities and differences between the various teacher's manuals. For example, the teachers found Silver Burdett suggestions to consistently include more

activities for pupils whereas Merrill manuals tended to emphasize more reading. Interestingly, teachers reported actually using more of the Merrill suggestions than those in Silver Burdett. On the other hand, the Merrill manuals had more background material for teachers and emphasized learning scientific vocabulary and concepts significantly more than the Silver Burdett series. Silver Burdett evaluation suggestions were found by the teachers to be more diverse.

AN ANALYSIS OF THE QUESTIONING LEVEL OF JUNIOR HIGH SCHOOL SCIENCE TEXTBOOKS

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An analysis of the cognitive level of questions within the primary junior high school science textbooks was undertaken utilizing the question classification scheme developed by Costa (1985): input, processing and output. The cognitive level of questions was analyzed in relation to textbook series, chapter, discipline, and location within chapter. Significance was determined based on questions per sentence, with the level of significance set at P = 0.01. A two-way ANOVA was used to determine significance for textbook series by question level and discipline by question level, followed by Tukey's pairwise comparison. A one-way ANOVA was used to determine significance between chapters within a textbook. Percentage comparisons were made within textbook series by question location. No significant difference in question level frequency occurred in the textbook series, chapters, or disciplines analyzed. There was a significant difference among the cognitive level of question frequencies within textbook series, with the frequency of low level cognitive questions significantly exceeding the frequency of high level cognitive questions. The emphasis on low level cognitive questions has several implications for science teaching, including the need to develop and integrate higher level questions and activities into instruction requiring students to process current textural information for more meaningful learning.

Invited Session

DO'S AND DON'TS OF WRITING FUNDABLE PROPOSALS

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The skilled "Grantsman" must be able to identify the critical elements in each funding situation and respond appropriately with a unique approach that is both creative and do-able. This seminar will explore the elements of successful proposal writing and external funding options for science education at the pre-college and college levels. The major components of the "typical" proposal are outlined step-by-step. Practical planning and writing tips for enhancing the probability of a funded proposal will be discussed. Sources of funding from state, federal, foundation and corporate sources are outlined and discussed. Specific topics covered in the seminar are:

1. Variations in the process
   a. The sources of funds
   b. The political process
   c. The types of proposals - Program or project, development or demonstration, training, planning, research, construction, and equipment
2. The key people to involve in planning
   a. Networking - Fellow workers, governing board, population to be served, affected organizations or agencies in the community, relevant federal and state agencies or local government
   b. Private sector - Foundations, small businesses, corporations
3. Key characteristics of a good proposal
   a. The idea is important and addresses a significant need
   b. A thorough plan for conducting the project is evident
   c. The applicant has the capabilities required to make the project successful
4. Overall characteristics of a good proposal
   a. Appropriate emphasis on established need
   b. Consistency
   c. Careful attention to directions
   d. Appropriate use of appendices
   e. Appropriate length
   f. Good structure
5. Proposal Components
   a. Standard formats
   b. Exceptional requirements
6. Procedures and Techniques for:
   a. Assessing needs
   b. Establishing objectives
   c. Developing activities
   d. Clarifying outcomes
   e. Measuring project effectiveness

Paper Set

COGNITION IN INFORMAL SCIENCE SETTINGS: REVIEWING VISITOR RESEARCH STUDIES

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Research has been conducted for a number of years in informal science settings. Much of that research has concentrated on describing who the visitor is, what is his/her motivation for being there, and what she/he does once there. There is also considerable research suggesting how exhibits can be designed utilizing attentional adjuncts and sequencing to maximize visitor attention, processing and the recall of exhibited material. As in other settings, however, there is an increasing sense of the importance of visitor knowledge and experience and a desire to understand the effects of these factors on the museum visit.

These three papers represent innovative efforts to understand cognition in informal settings. The first paper discusses long term learning from visits to informal learning settings, the second paper discusses the long term effects on visitor's attitudes of a zoo's efforts to educate the public about wildlife conservation, and the third paper explores the effects of visitor's perspective and perception on a visit to a zoo.

Informal Discussion

"AN HOUR WITH..."

Rodger Bybee
NARST Research Coordinator

or

Russell Yeany
JRST editor

This session on the 1989 NARST program provides NARST members with the opportunity to talk informally with either the NARST research coordinator about possible research activities for the organization or with the JRST editor about the preparation of manuscripts for the journal.

Paper Set: Problem Solving

REPRESENTATION AND PROBLEM SOLVING

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New Brunswick, NJ 08903

Sheila F. Pirkle
Southeastern Louisiana University

This paper set describes research related to knowledge organization and representation in individuals. Access to the manner in which knowledge is organized and represented internally is gained by examining the interaction of a given subject with the problem simulation presented in a computer monitor. Individuals are given kinematics problems in the form of a sequence of responses to the sequence diagramatically on paper. After each simulation, they contrast their response to the one presented on the computer screen. The changes in their responses to the problem sequence provide basic information for making inferences about the internal organization and representation of knowledge.

The problems selected were based upon a phenomenon about which every individual has some general awareness and common understanding. The problems involved projectiles shot from a gun. The problem series presents a sequence of phases, each of which builds upon the previous one. The sequence requires the subject to continually restructure the problem elements in new and extended environments.

The problem sequence is presented to individual subjects via a clinical interview. Once the subject has presented his/her view of the problem phase, it is graphically simulated on the computer screen. The subject can then compare his/her interpretations of events with that generated by the computer. This provides a mechanism for exploring the interactions between the subject's internal representation and those generated with the computer simulation.

These research reports involve subjects from the junior high school, high school, college, and graduate school. Gender as well as cultural differences are also examined. In general the subjects who made the greatest progress in the sequence were those who were able to use the simulations in monitoring their own problem solving approaches. Their representations appeared to be better integrated. They tended to consider phenomena such as the object path as a whole rather than as component parts. Their representations were more abstract in the sense that only the more salient features of the problem situation were presented. Their representations apparently enabled them to recognize relationships involved in the problem as well as to better analyze and respond to various aspects of the simulations.

Various cognitive abilities appear to be associated with well integrated abstract representational systems. These abilities appear to be closely associated with generating, restructuring, and refining problem representations. The individuals who have developed these abilities appear to be on the way to becoming successful problem solvers. The individuals who demonstrated a greater range of cognitive abilities, although classified as novices in relation to their knowledge base, made significant progress toward higher levels of problem solving in projectile motion. Those most lacking in these abilities related to organizing and processing information in relation to representation appear to be the factors that differentiate the most successful problem solvers.

Symposium

INFORMATION TECHNOLOGIES AND SCIENCE EDUCATION
1988 AETS YEARBOOK

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During this symposium, the editor of the 1988 AETS Yearbook will present an overview of the publication and ten of the authors will discuss salient issues from their chapters. Ample time will be provided for open discussion of important issues related to the integration of information technologies in science education.

Special Session

INVITED TUTOR ON WRITING GRANTS

Allen Schmieder
Chief, Title II Grants
U.S. Department of Education
Washington, DC

This session provides NARST members with an opportunity to obtain assistance in developing fundable proposals.

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Symposium

EPISTEMOLOGICAL ISSUES IN SCIENCE EDUCATION

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Ever since the publication of Kuhn's The Structure of Scientific Revolutions in 1962, there has been a growing acceptance of new ideas regarding the growth of knowledge in sciences. Also over the past two decades there has been developing a new cognitive psychology of learning that places emphasis on the role of prior knowledge held by learners as a key factor in new learning. Both from the psychological and philosophical perspectives, recognition of the evolving conceptual-nature of knowledge and meaning making has occurred. These emerging ideas have significance both for curriculum design and pedagogy in the sciences.

This symposium will present recent research on psychological views of learning held by students and also their epistemological ideas. The interrelationships between student learning patterns and their epistemological ideas will be explored. A study of scientists' views on new knowledge production and related views on learning and teaching science will be presented. A study on "world views" held by students and science professors will be reported. Some discussion of gender as a factor in science research and learning will be included. Each report will consider implications for science education.

Research on relationships between students' epistemological views, science learning and attitudes toward science is still in its infancy, but studies done to date suggest high significance and importance for such research. The discussion period will explore possible avenues for further research.

Symposium

TEACHING SCIENCE CONCEPTS WITH ANALOGIES

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Traditional science instruction does not often result in meaningful learning which involves the construction of relationships between existing knowledge and new knowledge. This symposium will focus on the use of analogies to connect old knowledge with new knowledge when teaching science concepts. Good analogies can facilitate comprehension and recall of new learning by bridging the gap between what the student already knows and the new information the student is asked to learn. Each presentation in this symposium will discuss research with science analogies and illustrate how analogies can be used to effectively teach science concepts.

The first presentation, Teaching Photosynthesis to Middle School Students Using Analogies, focuses on teaching the science concept of photosynthesis to middle school students. In the first stage of the research, 75 middle school students' conceptions and misconceptions of photosynthesis were examined. In the next stage, the potential value of teaching the concept of photosynthesis by analogy was assessed. Specifically an analogy was drawn for the students between the unfamiliar concept of photosynthesis to the potentially familiar process of baking a cake.

The second paper, Promoting Learning through the Use of Analogies in High School Biology Students, reports the effects of extended verbal analogies on students' immediate and delayed recall of science content. The treatment consisted of written passages eight or nine pages long dealing with each of two biology concepts, evolution and cellular respiration. The control version of the text was similar but lacked analogies. Data analyses revealed significant differences in biology achievement in favor of the analogy treatment group on the evolution immediate recall test ($p = .038$) and on the delayed recall test covering both topics ($p < .001$). An achievement difference on the cellular respiration immediate recall test, while in favor of the analogy treatment group, was nonsignificant.

In the third presentation, Explaining Physical Science Concepts: A Teaching-With-Analogies (TWA) Model, the important role that analogical reasoning can play in learning physical science concepts is discussed. In high school and elementary school science textbooks, well designed analogies can prompt students to establish meaningful relationships between physical science concepts. The physical science analogies in 29 high school and elementary school science textbooks were examined. The most effective analogies contained key features which have been incorporated into a Teaching-With-Analogies (TWA) model.

In conclusion, the three papers to be presented will argue that one of the most effective ways for science students to integrate their existing knowledge with new knowledge is to do so by means of analogical reasoning. Teachers and text authors can provide analogies for students, and students can be trained to generate their own analogies.

PROCESS SCIENCE AND STANDARDIZED TESTING: ARE THEY COMPATIBLE?

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Historically, science educators have been most critical of the use of standardized tests to assess mastery of science content. The fact of the matter is, however, that there has been an increase in the administration of, and frequency of, standardized testing in the last decade. Standardized testing, as viewed by many administrators and school boards members, is an essential and integral part of the process of schooling. A traditional orientation to instruction and testing, however, conflicts with the current reconceptualist goals in science education.

It was apparent that science educators face a serious challenge as we approach the 1990s. How can we begin to address and implement reconceptualist goals in a traditional schooling environment? With the preceding question in mind, we raised a more pragmatic question: Can the data derived from standardized tests be compelling enough to support the continuance of curricular innovations?

This study was designed to assess the effect upon student achievement of one, two, or three years of a process science curriculum. The Iowa Tests of Basic Skills (ITBS) Complete Battery with the social studies and science supplements was administered to sixth grade students completing one, two, or three years of the Science Through Discovery program in Richardson Independent School District (TX). In order to compensate statistically for pretreatment differences in achievement, students' third grade scores on the Comprehensive Test of Basic Skills (CTBS) were selected as a covariate.

Discussion will focus on the results of the data analysis by treatment and treatment x gender. In addition, post hoc analyses were conducted to address the issue of gender equity or disparity as a function of the curriculum being implemented and/or testing procedures. The results of this study should provide valuable information to science educators and school districts wishing to implement comprehensive K-6 curricular innovations.

THE DEVELOPMENT OF THE PERFORMANCE OF PROCESS SKILLS (POPS) TEST FOR MIDDLE GRADES STUDENTS

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The purpose of this project was to construct a valid and reliable non-curriculum-specific measure of integrated science process skills intended for use with middle school students.

The major efforts in test development were focused on the refinements and modifications of the set of objectives and test items assessed by the existing Middle Grades Integrated Science Process Skills Test (Cronin and Padilla). Each objective and item was carefully analyzed to ensure that it was a valid representation of the intended process skills. Skills associated with planning, conducting, and interpreting results from investigations were delineated, and six objectives encompassing these skills were identified. Twenty-one items judged to be the best measures of these objectives were chosen for inclusion in the test. Modifications were made on the items in order to provide additional explanation for specific terms, i.e., the manipulated, responding, and controlled variables. The POPS test was constructed in order to assess the process skills dealing with identifying experimental questions (three items), identifying variables (six items), formulating hypotheses (three items), designing investigations (three items), graphing data (three items), and interpreting data (three items). The readability of the test was assessed using the FOG index, and the average grade level index of 6.8 was obtained. To establish content validity, objectives and items were submitted to a panel of reviewers. The responses of the four experts were consistent on almost all items in terms of indicating the correct answer and keying to a process skills objective. This concurrence of reviewers was taken as evidence of content validity and objectivity of scoring.

To examine test reliability and item indices, the POPS test was administered to middle school students in grades six through eight. A total of 1,402 students were involved in this field test. Total scores on the 21-item test for overall students ranged form 1 to 20 (Mean = 9.8, S.D. = 4.2). Total test reliability (KR-20) was .75. Item difficulty

indices ranged from .28 to .79 with an average of .47. Item discrimination indices obtained by using the upper 27% and lower 27% of the sample group showed that 20 of the 21 items were above .30 with an average of .41. Each of these indices fell well within the acceptable range for a reliable test.

These results provide evidence of the reliability and validity of the test. The POPS test is a reliable instrument for diagnostic and/or summative assessment in science classes or research studies. The test may be a useful means in classroom-based research, evaluation of instruction and learning, and curriculum validation in evaluation as well as assessing process skills competence of middle school students.

A QUALITATIVE ANALYSIS OF STUDENT RESPONSES ON A TEST OF BASIC PROCESS SKILLS

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Currently, the assessment of basic process skills is under the close scrutiny of the educational community. Considerable effort is being put forth by national educational organizations in developing instruments that assess higher order thinking, which includes both basic and integrated process skills. Methods of assessing these skills, such as paper and pencil, station, and interview tests, are also being examined. It is the purpose of this paper to examine student responses on a basic process skills test from a qualitative perspective and compare student responses with those multiple choice alternatives provided by the test writers. The data gathered from this study will be used in improving the quality of a Test of Basic Process Skills (BAPS) by providing more viable distractors.

The Test of Basic Process Skills (BAPS), for elementary students, measures the skills of observation, communication, classification, measurement, prediction, and inference. This test contains six items of varying difficulty for each identified process skill in a multiple choice, four option format. BAPS reliability (KR-20 = .82) and content validity were reported in a previous study in which the multiple choice answers were included.

For this study, the format of the BAPS Test was changed from a four option, multiple choice format to an open-ended response format. This was accomplished by eliminating the multiple choice answers, rewording the question, and providing space for student responses. Additional statements within the test asked students to explain their reasoning in determining their answers. Item complexity and style were not altered.

The open-ended response BAPS test was administered to twenty-nine students in a small, rural Pennsylvania school system in grades 4 through 8. After the students completed the test, the researchers reviewed the individual's test and asked the student how each answer was obtained. Student responses were either written or tape recorded by the researchers.

Major trends within the group have been examined. The data collected indicate that multiple choice tests are limited in finding out how a student determines the correct answer. Through the use of open-ended tests, where children are asked to explain how the answers were acquired, reasoning patterns can be studied. In designing tests of basic process skills, it is essential to be familiar with student reasoning patterns and to present distractors that are plausible to the student.

A STUDY OF THE IMPORTANCE OF REFLECTION FOR IMPROVING SCIENCE TEACHING AND LEARNING

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A three year naturalistic case study involving 22 novice and experienced science teachers, over 250 secondary science students at five schools, and the authors, is described. The study is directed to enhancing participants' expertise in science teaching and learning through collaborative reflection and action. Reflection is both individual and group based and of two main types: reflection on practice as part of on-going classroom action research; phenomenological reflection on the nature of science teaching and learning as experienced by the participants.

The study is interpretive in its approach, and incorporates in its design and manner of implementation some recent understandings in the fields of metacognitive training, constructivism, and the nature of individual change. It involves teachers and students working together to devise ways of changing classroom attitudes and behaviors in order to generate desirable cognitive, metacognitive, and affective outcomes.

Findings from the study illuminate aspects of the nature of science teaching and learning, processes by which individuals improve the quality of their practice, and methodologies for exploring teaching/learning mechanisms and facilitating change. Central to these findings has been the importance of each of the two types of reflection mentioned above for fostering personal and professional development. For both teachers and students, both types of reflection have acted to improve their knowledge, awareness, and control of themselves and their classroom practice.

In the study, personal and group development have been shown to depend on classroom participants and consultants exercising certain necessary responsibilities. As will be discussed, the nature of these methodological imperatives for the improvement of science teaching and learning has implications for the design and implementation of effective pre-service and in-service teacher education.

BIOLOGY CONTENT COGNITIVE STRUCTURES OF BIOLOGY MAJORS, BIOLOGY TEACHERS, AND SCIENTISTS

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The F-Sort of Biology Concepts was used to assess understanding of the relationships among 37 biology concepts by five groups:

1) Preservice secondary science teachers (PSR).
2) Inservice biology teachers with 1-3 years of teaching experience (NOV).
3) Inservice biology teachers with 5 or more years of experience (EXP).
4) Scientists in any biological science field (e.g., microbiology, botany) (SCI).
5) College seniors majoring in biology (MAJ).

Data collected from the F-Sort of Biology Concepts were analyzed using Latent Partition Analysis and Alpha Factor Analysis with additional interpretation from multidimensional scaling. The subjects were asked to think aloud as they performed the F-Sort and each session was audio-taped for later analysis. These analyses indicate that the biology major (MAJ) and experienced secondary science teachers (EXP) were separated from the scientists by a dimension based on a deep versus surface structure understanding of the concepts. A second axis shows that the biology majors (MAJ), NOV, and PSR separated from EXP by an academic course versus teaching unit dimension. That is, EXP categorized concepts based upon the teaching units the concepts would be found in at the secondary level, whereas the other groups reflected an organization much like that found in a college course such as embryology, cell biology, or biochemistry.

It appears that teachers restructure their science knowledge as they become more experienced. There is an apparent transition from poorly organized to highly organized cognitive structures for biology concepts when comparing PSR, NOV, and EXP respectively. The transition does not seem to be one achieving a deeper understanding of the biology concepts or to a greater degree of integration of the concepts, but rather a transition from a fairly large, loosely organized pool of biology concepts to one which is highly structured but limited to the expectations of the established curriculum.

The results have implications for the well-known conjecture that teaching helps one to better understand the content being taught.

UNIVERSITY RESEARCHERS' INCHOATE CRITIQUES OF SCIENCE TEACHING: A CASE FOR THE STUDY OF EDUCATION

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There is general agreement that current teaching of secondary science is not as good as it should be. Different critics identify different weaknesses, but there is agreement that students are not learning how scientists make knowledge claims and use this knowledge. This paper assumes that one powerful influence on the development of teachers is the way thay have been taught.

An examination of conceptions held by scientists teaching university science courses indicates that university science teaching may have adverse influence on the development of secondary science teachers. The difficulty the researchers identify is that university science teachers take most aspects of teaching for granted and lack the theoretical framework to critique teaching practices and develop alternatives.

We propose that viewing teaching as a research activity would help those scientists interested in teaching to examine and revise their own conceptions.

THE DEVELOPMENT OF SCIENCE CONTENT PEDAGOGY AND THE IMPACT ON PUPIL LEARNING

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The development of the pedagogical knowledge of middle school teachers has been treated in a very general fashion. That is, they receive an introductory level education in many content areas and a significant amount of exposure to general classroom pedagogy. There often is little or no attempt to insure that they are well grounded in content pedagogical knowledge as defined by Shulman in his discussion of the missing paradigm. This study shows that the paradigm is valid and that helping teachers to develop this knowledge will lead to changes in the classroom and these changes will lead to improvement in learning on variables that we hold near and dear to our professional hearts.

The major purpose of this study was to assess the effectiveness of teacher development activities which focused on content pedagogy related to the teaching of science at the middle school level. The emphasis was on the teaching of logical reasoning and science processes, as well as the desired science content.

Middle school teachers were provided with training in science content pedagogy regarding the proper use of manipulatives and other hands-on and minds-on experiences. The objective of this training was to develop the teacher's content pedagogical knowledge regarding the teaching of reasoning and process skills as well as science content and, as a result, to influence the learning of middle school pupils.

The experimental group was composed of all 6-8 grade teachers and their students in two middle schools in Georgia. The control group was composed of a stratified random sample of students from four other middle schools in the same district who had not received similar treatment and which were similar in demographics to the experimental schools (N = 1250). For the performance interview testing, a stratified (race and gender) random sample of 35 students was drawn from the larger samples of both experimental and control students for a total of 70 students in this sub-example.

THE INFLUENCE OF TASKS ON STUDENTS' MOTIVATION AND THOUGHT IN SCIENCE

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This study was designed to examine how tasks influence student motivation and the quality of cognitive engagement during science lessons. Fifth and sixth graders (N = 275) were drawn from 10 science classes taught by five teachers. Sixty lessons (6 per class) which varied with respect to product, lesson, content and structure were observed. After each lesson students completed questionnaires designed to assess their motivation to master the material and their use of learning strategies. Tasks were categorized on the basis of product (number of questions and percent of high level questions), lesson content (number of facts and ideas presented by the teacher), and structure (whole group, small group, and individual).

Correlational analyses and MANOVAS indicated that: (a) products were not significantly related to student active learning, but length of product affected motivation, (b) level of lesson content influenced motivation and active learning but the influence differed by structure, (c) active learning was lower in small groups but motivation was higher, (d) teachers had a significant influence; students in some classes indicated they were more motivated and that they made greater use of learning strategies.

THE REFLECTION OF NONSCIENTIFIC BELIEFS AS A FUNCTION OF INSTRUCTION AND REASONING ABILITY

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To test the hypothesis that hypothetico-deductive reasoning ability facilitates the rejection of nonscientific beliefs, 954 college students enrolled in an introductory nonmajors biology course were pretested to determine the extent to which they believed in the scientifically outdated ideas of vitalism, the soul, teleology, orthogenesis, reductionism, and special creation. They were also pretested to determine their reasoning

ability (intuitive, transitional, reflective). As predicted, a greater percent of intuitive thinkers initially held nonscientific beliefs than their transitional and reflective peers. Also as predicted, posttesting showed that the intuitive thinkers were less likely to discard their nonscientific beliefs during the semester. Thus, support was obtained for the study's working hypothesis. The strength of commitment to a scientific belief was also related to reasoning ability. On most items where both intuitive and reflective thinkers held the scientific belief, the reflective thinkers tended to strongly agree with the scientific belief while the intuitive thinkers merely agreed. In retrospect this seems understandable. If one does not recognize the logical basis for a scientific belief, one is less likely to be strongly committed to that belief. Teachers should be aware that some students hold alternative beliefs and that some have poorly developed reasoning abilities. Teaching methods which allow students to openly voice and test alternative beliefs should result in two important products: 1) students with a greater awareness and facility with the reasoning abilities needed to test alternative beliefs; and 2) a set of beliefs more in line with those of modern science.

CONTROLLING ONE'S OWN COMPREHENSION IN LEARNING SCIENCE: EVALUATION AND REGULATION STRATEGIES

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Metacognitive variables influence students' learning from science texts. This work deals with the comprehension monitoring abilities of secondary school science students, one of the areas of metacognition which has drawn considerable attention from researchers. The aims of the study are (a) know the extent to which comprehension is monitored by secondary science students as revealed by inconsistency detection in manipulated science texts, and (b) identify the strategies used to regulate comprehension by the students who detect the inconsistencies.

A classification is presented of the reactions of the students to the manipulated texts. The numerical results indicate that knowing that one understands or fails to understand science texts could be as important a problem as understanding proper in the beginning secondary school years. Also, some incorrect regulatory strategies used by students who notice the inconsistencies in the texts are identified.

ACHIEVEMENTS IN EIGHTH-GRADE SCIENCE BY BOYS AND GIRLS OF FIVE ETHNIC GROUPS

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In 1986 and in 1987, a statewide assessment program measured the achievements in science of five ethnic groups of eighth graders. Approximately half of each group was boys or girls. The importance of understanding achievements among these students of different groups and gender is emphasized by the national concern to correct the predicted shortfalls in America's science and engineering work force. The Congress of the United States, Office of Technology Assessment in 1988 observed: "Women (and, to a lesser extent, Blacks and Hispanics) raised their rates of participation in science and engineering during the 1970's; while these gains seem to have leveled off in the 1980's, there is no reason to believe that participation cannot be further increased."

Each year, almost 300,000 English-speaking students in grade 8 were tested in one state. Each student completed a test form including 15 multiple choice achievement items. The matrix sampling method, by using 36 unique forms, allowed approximately 8,000 students annually to complete each of the 540 science achievement items. The matrixed forms were distributed randomly to students within any class.

The 540 items of the test consider six major areas: (1) items on the biologica sciences constituted 21% of the test; (2) earth science, 15%; (3) physical science, 21%; (4) science, technology, individuals, and society, 8%; (5) safety and manipulative skills, 5%; and (6) science process skills, 30%. Each of these six areas has several subcategories. For example, biological sciences has the subcategories of cells, plants, protists, animals, human beings, ecosystems, genetics, and evolution. Science processes consist of observing, comparing, organizing, identifying relationships, recognizing hypotheses, experimenting, interpreting, and inferring. The results on all areas and subcategories are reported to each school district.

Gross analysis of achievement results across the major areas of the science test in the spring of 1986 and of 1987 showed large differences in percent correct between the highest and the lowest scoring ethnic groups, i.e. by approximately 14 to 17%. The usual sequence from the highest to lowest scores is the following: (1) White, (2) Asian, (3) others, (4) Hispanic, (5) Black.

Boys scored significantly higher than girls in almost all categories. Gender differences were significant among all ethnic groups except Blacks. Boys significantly outperformed girls in 19 of the 20 categories of the biological sciences, earth sciences, and physical sciences, and in three of the five categories in science, technology, individuals and society. Girls sometime outperformed boys: in one category of safety and manipulative skills and in one of the eight categories of processes, i.e., in observing.

Achievements on the items were higher in 1987 than in 1986 for most categories of all groups. The pattern of superior achievements by boys over girls continued with a trend for the differences to widen.

A LONGITUDINAL STUDY OF STUDENT OUTCOMES AND TEACHER CHARACTERISTICS IN EXEMPLARY MIDDLE AND JUNIOR HIGH SCIENCE PROGRAMS (TEACHER RESEARCH PARTNERSHIP PROJECTS OF NSTA AND CALIFORNIA STATE UNIVERSITY)

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Collaborative "research partnerships" between university researchers and classroom science teachers have been encouraged by recent efforts of both the National Association for Research in Science Teaching (NARST) and the National Science Teachers Association (NSTA). In 1987, the Middle and Junior Division of NSTA and a university began a longitudinal teacher research partners study to examine student outcomes and teacher characteristics in the NSTA/NSF identified middle/junior high exemplary programs. The second year of the study was funded by a grant from another university.

In the first year key teachers in the Search for Excellence in Science Education (SESE) Exemplary Middle/Junior High Programs examined their own seventh and eighth grade student outcomes in three domains of science education: (1) knowledge, (2) attitudes, and (3) applications/connections, using the Iowa Test of Basic Skills and National Assessment of Educational Progress (NAEP) items. Results were compared with national populations. The second year an additional applications instrument was included.

Teachers were surveyed using two questionnaires, one from the Report of the 1977 National Survey of Science, Mathematics and Social Studies Education, and another asking supplemental questions.

The first year results indicate that for exemplary middle/junior high science programs: (1) Teachers are highly experienced (average 18.5 years teaching). All feel well qualified, are highly enthusiastic about science teaching, use professional journals as resources, and find other teachers their greatest professional inspiration. All make presentations at professional meetings, ninety-one percent at national meetings. They use a rich mixture of teaching strategies allowing students active exploration of their natural world. (2) Students score far above the national norms, 87 percentile rank (year 1) and 81 percentile rank (year 2), on a standardized test of science knowledge. (3) Students have strong positive attitudes toward science in most areas. Science is the first or second favorite course for 48%, compared to 29% for students generally. Compared with the national sample, students report significantly higher attitudes toward science classes with regard to comfort, success, curiosity, and preparation to make decisions. (4) Students generally do not perform higher in the applications domain than do students in general. (5) Boys show slightly higher scores than girls in most areas. In the second year, similar overall results were obtained.

This study has shown that in exemplary middle/junior high programs: (1) students can learn both science knowledge and maintain or develop positive attitudes toward science, (2) students need opportunities to make connections between what they learn in science and personal responsibility, (3) girls need specific assistance to enhance their involvement in science. The longitudinal teacher research partnership study will continue in cooperation with the Middle/Junior High Division of NSTA and a university, to study student outcomes in outstanding science programs. An invitation for general voluntary participation from middle school teachers will be issued in 1989. The study will increase the opportunity for teachers to join with other teacher researchers to monitor and evaluate their own curriculum goals and teaching strategies as professional science educators in partnership with a university researcher.

THE RELATIONSHIPS AMONG ALTERNATIVE PHYSICAL SCIENCE CONCEPTIONS, FORMAL REASONING ABILITY, AND SCIENCE BACKGROUND

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This study investigated the intercorrelations among alternative physcal science conceptions, formal reasoning ability, and science background of preservice teachers. The Test of Alternative Science Conceptions (TASC), developed by the researchers, revealed common alternative physical science conceptions among 219 preservice teachers enrolled in elementary and secondary science methods classes in a southeastern university. The Test of Logical Thinking (TOLT) was used to assess the formal reasoning ability of the preservice teachers. A survey was used to assess the content background in the subjects of biology, physics, chemistry, geology, and astronomy.

The Pearson product moment correlation revealed significant correlations between performance on the TASC test and formal reasoning ability. This finding provides evidence that formal reasoning ability is needed to enable subjects to evaluate alternative physical science viewpoints. Significant correlations were also found between performance on the TASC test and the number of completed university science courses, thus suggesting that science content courses help change human-centered viewpoints.

QUANTITATIVE AND NATURALISTIC RESEARCH STUDY ON EXEMPLARY CHEMISTRY TEACHERS

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The research on exemplary teachers was found to be effective in trying to improve science instruction and schooling. This study is a combination of a naturalistic and a statistical (quantitative) study.

Four exemplary and seven average (non-exemplary) chemistry teachers were selected on the bases of classroom and laboratory observations. The exemplary teachers were characterized by a good control of the subject matter, good classroom management and awareness to students' learning difficulties. It was also found that these teachers tried to vary classroom practices, and their lessons were well prepared and organized. The average-type teachers were low on these variables.

In order to find out how students perceive their teachers and their classroom learning environment, two questionnaires were administered: a "learning environment" an and attitude questionnaire. The students who studied chemistry in classes taught by exemplary teachers found the learning environment less formal, more satisfactory, more goal directed and more varied, compared to students who studied chemistry in the average-type teachers' classes. It was also found that students who studied chemistry in the exemplary teachers' classes had a more positive attitude towards chemistry as compared to the non-exemplary classes. At the end of the year, it was found that enrollment in further chemistry courses was much higher amongst students who were taught by exemplary teachers. On the basis of these findings one could construct a model of teaching that could be used for training teachers, both preservice and inservice.

INTELLECTUAL DEVELOPMENT, SCIENCE ANXIETY, AND CONTENT ACHIEVEMENT IN PRESERVICE ELEMENTARY TEACHERS

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This study investigated preservice elementary teacher reasoning ability levels, science anxiety levels, and content achievement in a large midwestern university. Pretest and posttest measures were taken on three dependent variables: (1) reasoning ability (cognitive development), (2) science anxiety, and (3) science content achievement. In addition, relationships between reasoning ability, science anxiety, content achievement, microteaching experiences, and final grades were explored. A sample of 74 students enrolled in a science methods course for preservice elementary teachers participated in this study.

There were significant differences, pretest-posttest, following 14 weeks of instruction in (1) reasoning ability levels ($p < .01$), (2) science anxiety levels ($p < .001$), and (3) content achievement ($p < .001$). Science anxiety, content achievement, and final grades correlated moderately with reasoning ability. There was no significant correlation between science anxiety, content achievement, and reasoning ability with peer microteaching scores. However, final grade correlated moderately with peer microteaching scores.

The results of this study lend support to the notion that inquiry-oriented, hands-on, process-approach science activities which encourage social interaction may enhance formal reasoning skills. Furthermore, the evidence suggests science anxiety may be lessened and content achievement increased during these kinds of activities. These findings may be of particular interest to science educators since primary educational goals leading to more effective elementary science teaching include an increase in student reasoning ability and a decrease in science anxiety.

MONITORING STUDENT VIEWS ON SCIENCE-TECHNOLOGY-SOCIETY TOPICS USING A MULTIPLE-CHOICE FORMAT

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The study surveyed a national sample of Canadian anglophone and francophone (Quebequoi) grade 12 students in order to establish standard responses to 33 multiple-choice items, the first batch of a new inventory pool called Views On Science-Technology-Society (VOSTS). The development of the items followed a new process by which the item choices are generated from empirical data (students' argumentative paragraph responses) rather than from the philosophical stances of science edcators.

Because the items are detailed enough for students to express reasoned viewpoints, a researcher is able to determine the logical basis upon which the viewpoints are grounded. The results are useful to curriculum developers of future classroom materials dedicated to teach science through STS. VOSTS items uncover naive conceptions about science and about how science authentically functions in a society increasingly shaped by science and technology.

The sample was comprised of grade 12 students in rural and urban Canadian anglophone schools (N = 1700) and francophone schools (N = 700). The frequency of responses to each VOSTS item choice was calculated and the relationship of these choices to the literature on scientific literacy was detemined.

The various reasons that explain student views will be systematically reported in the paper for all 33 VOSTS items. Topics fall under the following headings: science and technology, the influence of society on science/technology, the influence of science/technology on society, characteristics of scientists, social construction of scientific knowledge, and the epistemology of science.

CHANGES IN SCIENCE ATTITUDES AND CORRELATES OF SCIENCE ACTIVITIES OF URBAN MIDDLE SCHOOL STUDENTS

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This longitudinal, cross-sectional, multidimensional study involved 1,946 urban middle school students from the southeastern part of the United States. The questions asked in this study were: (1) Are urban middle school students' attitudes positive or negative?, (2) Will the attitudes of students change over time?, (3) Are the changes in attitudes of students dependent upon gender?, (4) Are the changes in attitudes of students dependent upon grade level? and (5) Are the changes in attitudes of students dependent upon gender and grade level?

The Simpson-Troost Attitude Questionnaire, in addition to demographic information, was used to find the answers to these questions. The questionnaire was administered three separate times to the urban students in three middle schools throughout the school year.

Means and standard deviations of the scores on the subscales of the Simpson-Troost Attitude Questionnaire were calculated. In addition, a multivariate analysis of a repeated measure one between and two within design was done. The between variable was the subscale variable on the Simpson-Troost Attitude Questionnaire and time, the within variables were gender and grade level.

The results were as follows:

1. Students had a very positive attitude toward science. However, these attitudes changed significantly over time in a negative manner. In addition, the students' attitudes toward science changed significantly by gender and by grade level over time.
2. Urban middle school students had a somewhat neutral attitude toward science classes which did not change.
3. These students' attitudes toward other students were neutral and did not appear to change.
4. Student attitude toward the science curriculum did significantly change over time, and by grade level over time.
5. There was a significant negative change in the student attitudes toward the physical environment of the science classroom over time and by grade level over time.
6. Student attitudes toward their science teacher changed negatively over time, and over time by gender.
7. These students did not appear to be anxious about science and their anxiety level remained the same over time.
8. The urban middle school students did not have a very positive attitude toward school, these attitudes were more neutral.
9. The subjects in this study had a very high general self-concept; their self-concepts did not change over time.

10. There were no significant changes in the science self-concept of these students. Their self-concepts remained neutral.
11. These students were highly self-motivated; there was no change in their self-motivation.
12. They perceived that their friends' attitudes toward science were neutral and remained so over time.
13. These students liked their family and felt their families' attitudes toward science were neutral.

TEACHER ATTITUDES AND TEACHING STRATEGY EFFECTIVENESS

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The present study was conducted to explore teachers' attitudes regarding the effectiveness of a variety of instructional strategies, the extent of their current skills in using those strategies, and the extent to which those strategies have been emphasized in their training. A two-page survey to assess teacher attitudes on these issues was developed and sent to the members of a state biology teachers association and two groups of teachers participating in an NSF funded inservice program. The list of 23 teaching strategies was divided into two groups and those strategies generally found to be less effective (i.e. lecture, the use of textbooks, memorization of facts, and student worksheets) were analyzed separately from those considered to be more effective (the 19 remaining strategies).

For the effective strategies, it was found that teacher ratings of effectiveness were high (above 4 on a 5-point scale), but teacher ratings of their own skills was significantly lower. Ratings of the effectiveness of the less effective strategies were, not suprisingly, lower; but the teachers' skill ratings were higher than for the effective strategies. This result occurred for each of the strategies, and regardless of the amount of inservice training indicated by the teachers. In addition, there were several of the effective strategies which a number of teachers indicated they were unfamiliar with, including wait time (18%), mastery learning (13%), promoting cognitive change (9%), pre-instructional strategies (7%), promoting conceptual change (6%), and using prior knowledge (4%).

This study raises the question of whether teachers are in fact less skilled at the more effective strategies or they only see themselves as less skilled due to the difficulty or perceived difficulty of the implementation of those strategies. An observational study to check the accuracy of the teacher ratings is suggested to clarify these data.

PERSUASION AND ATTITUDE CHANGE IN SCIENCE EDUCATION

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The purpose of the study was to analyze the complexities of persuasion. The orientation taken in the study was that science educators need to be acquainted with persuasion in the context of social influence and learning theory in order to be able to evaluate its usefulness as a vehicle of attitude change in science education.

For the most part, efforts to improve attitudes by science educators have taken the form of learning science content or comparing innovative forms of teaching with more traditional ones (e.g., museum tour vs. lecture). More recently, theoretical models derived from social psychology have been employed. The vehicle responsible for attitude change in all of the models is persuasion.

Persuasion refers to any change in attitudes that results from exposure to a communication and it embodies many aspect of teaching. Nevertheless, persuasion connotes unethical processes in the minds of many people. It is perhaps due to the disdain for anything that is linked with attempts to manipulate others that has served to discourage the use of persuasion as a vehicle for improving the science-related attitudes and behavior of students and teachers. Despite being associated with unethical processes, several theoretical models of persuasion have been operationalized and tested within the science education milieu.

Science educators have little reason to confuse persuasion with other forms of social influence. Propaganda is a type of persuasion directed toward a mass audience when viewed from a neutal perspective. However, today's definition presents propaganda as an intentional process to disrupt rational descision making. Coercion relies on reinforcement control, whereas persuasion is prompted by information. The recipient of a persuasive message is always free to accept or reject the appeal; the same is not true for coercion. Indoctrination and persuasion are both concerned with the change and formation of beliefs. They differ, however, in that in persuasion the emphasis is place on the reasons for the belief as opposed to the content of belief. Brainwashing refers to the coercive technique applied by the North Korean military to obtain the cooperation and compliance of POWs. Unlike persuasion, brainwashing involves physical brutality, psychological pressure, and intensive interrogation. As currently conceived, persuasion and instruction are much alike. Both require conscious cognitive activity by the recipient and involve communication which includes giving arguments and evidence for the purpose of getting someone to do something or to believe something.

Persuasion research is anchored in learning theory. Early efforts were based on classical and operant conditioning. Studies following Carl Hovland's approach focused on the effect of the variables harbored within the question, "Who says what to whom how with what effect?," on attitude change. Persuasion research in science education can be traced directly to Hovland's learning theory approach.

The cognitive response approach to persuasion and the theory of reasoned action represent extensions to Hovland's work. The cognitive response approach is concerned specifically with how people personally process the arguments presented in a persuasive message. The theory of reasoned action specifies the determinants of behavior and how changes in the determinants produce changes in behavior. These extensions to Hovland's work seem to be the most fruitful areas for future persuasion research in science education.

The ethics of persuading another person to believe something or to do something have always been questioned. Nevertheless, it is possible to be both ethical and persuasive. Altruism, that quality in an act in which no reward is expected, is presented as a standard against which to gauge the ethics of a persuader and his message. Because all persuaders are not motivated by altruism, Hugh Rank's intensifying/downplaying scheme is recommended to help the receiver guard against deceptive uses of language in persuasion.

USING CATEGORIZATION TO ENHANCE CHEMISTRY PROBLEM SOLVING SKILLS

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The enhancement of chemistry students' skill in problem solving through problem categorization was the focus of this study. Twenty-four students in an introductory chemistry course for health professionals were randomly divided into two different laboratory sections where one group was taught to categorize problems and the other group was given additional problems to solve during three laboratory sessions. All students were taught to use the Explicit Method of Problem Solving which is a heuristic based on the work of Polya and on the information processing model.

Data were analyzed using Multivariate Analyses of Covariance and Analyses of Covariance with The Logical Mathematical Reasoning Test as the covariate. Results indicated that there was a significant difference in problem solving achievement favoring the treatment group when problems were complex or when students were asked to solve problems unexpectedly.

A sample of six students from each group was also interviewed to determine their categorization skills and the processes that they were using in solving problems. Analysis of transcripts indicated that most students did indeed categorize problems correctly, but many did not recognize this as categorization when asked. Transcript analysis also indicated that students used a "Roladex" approach to solving the problems in that they appeared to match the problems' major features to algorithms or formulas stored on cards in their memory. Interviews also revealed that although most had firm knowledge of the chemical concepts that were related to the physical phenomena involved in the problem, they made no effort to use this knowledge in solving the problems.

This study has shown that explicit training in categorization skills when students use a structured format to solve problems can lead to higher achievment in complex problem solving situations. Although this positive result is encouraging, it also appears that the use of categorization skills combined with an explicit problem solving procedure does not maximize students' problem solving capability. Such achievement may be limited by the lack of linkage between students' conceptual understanding of the physical phenomena involved in the problems and their problem solving heuristics.

NATURALISTIC AND PSYCHOMETRIC PERFORMANCE OF EXPERT/NOVICES ON THE CATEGORIZATION OF CHEMICAL EQUILIBRIUM PROBLEMS

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The purpose of this investigation was to analyze the naturalistic and psychometric behaviors of a sample of subjects on the categorization and methodology for solving 24 selected chemical equilibrium problems. Also, I wanted to observe the "surface/deeper structure" feature of novices and experts described by Chi et al in physics problems, and Smith in classical genetics problems.

The sample consisted of 10 chemistry professors (E), 10 students who had completed 26 hours of college chemistry (M), and 25 students who had completed 8 semester hours of general college chemistry (N).

The naturalistic behaviors were observed by using the think-aloud technique in which the subjects were videotaped while they try to categorize the problems individually.

A 60-item test on chemical equilibrium (CET) was prepared and validated to analyze the psychometric performance on this topic of general chemistry.

As expected, the average score of the experts (42.90) was higher than was that of the group of novices who had completed more courses of chemistry (28.90); the novices with two semesters of chemistry scored lower (15.90).

The three mean scores were compared and found statistically significant at the 0.05 level by using a t-test and one-way ANOVA.

For chemical education and science education in general, the most interesting aspect of this study is the naturalistic behaviors of the groups while each subject read the problems, made categorizations, and showed how the problems could be solved.

Almost all novices demonstrated a general lack of chemical literacy which was reflected in many questions (eg: What is Ke, Kc, Kp, Ka, Kb, DeltaH°, DeltaG°) asked as they read the problems. They showed a general inability to name common substances (eg: acids, bases, oxides, salts) correctly. They could not distinguish or identify the classes of compounds present in each problem. They showed a large number of chemical misconceptions, made a large number of illogical classifications, and were unable to say how the problems could be solved.

In contrast, most experts made logical classes, identified the substances in each problem, read their names properly, solved several problems or said how they could be solved. However, some experts demonstrated lack of basic knowledge about the specific domain of chemical equilibrium in both the clinical interview and the test.

Since classification schemes are relevant in science, more attention should be given to developing the concepts of classes (eg: substances, reactions, problems) and heuristics for problem solving.

COOPERATIVE GROUPING AND CHEMISTRY PROBLEM SOLVING

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This study used cooperative grouping ideas and prescriptive problem-solving techniques in the content-specific area of high school chemistry problem solving to answer the following questions:

1. Does cooperative grouping enhance the problem-solving abilities of students in high school chemistry?
2. What are student and teacher attitudes about cooperative grouping?
3. Is proportional reasoning ability an important factor in chemistry problem solving?
4. What are the characteristics of successful vs. unsuccessful problem solvers?
5. How do such variables as math aptitude, age, gender, and proportional reasoning relate to chemistry problem solving?

One hundred and seventy-eight students in regular and honors chemistry classes in three public schools were the subjects in this study. Most honors classes consisted of tenth grade students while regular chemistry classes had mostly eleventh graders.

The three teachers were given instruction in using the prescriptive problem-solving strategy and in cooperative grouping techniques. Guidelines for the techniques dealt with reward interdependence, task interdependence, individual accountability, and teacher-imposed structure.

Based on the Test of Logical Thinking by Tobin & Capie, students in each of the experimental treatment classes (cooperative grouping) were categorized and then randomly placed in groups to ensure that each group would consist of students of differing proportional reasoning ability. The control treatment classes solved the stoichiometric problems individually rather than in groups, although both treatments used guides (prescriptive method) during the problem-solving process.

A chemistry pretest consisting of 12 multiple-choice items from the 1981 ACS/NSTA exam and two word problems was administered to all students prior to this seven-week study. A chemistry posttest consisting of seven multiple-choice items selected from the 1985 ACS/NSTA exam and three questions representing the four problem types used in the study was administered at the end of this seven-week study.

Students' attitudes about chemistry as a school subject were assessed (pre and post) using a modified version of the Science Attitude Scale, a Likert-style 24-item questionnaire.

At the end of the seven-week study, volunteers (N = 55) of varying proportional reasoning ability, from control and experimental treatment groups were asked to solve limiting reagent problems orally in groups of two or three while being videotaped. After students were given directions, they were left unattended while they solved the assigned problem.

Quantitative analysis of the data from the various measures did not show statistically significant differences between the experimental and control treatments. Although most students and all three teachers said they learned a lot about working in groups and they liked it, neither attitudes toward chemistry as a school subject nor understanding of chemistry as measured by a standardized test revealed advantages of working in groups during problem solving.

Analysis of the videotaped problem-solving sessions revealed a number of differences between successful and unsuccessful solvers including: 1) successful Ss wrote a balanced equation, 2) they determined a mole ratio from the coefficients, 3) they broke the problem into steps, 4) they labeled quantities with appropriate units, and 5) they exhibited persistence and confidence. Their unsuccessful counterparts showed fewer of these characteristics.

From this study it can be said that teachers and students in high school chemistry can learn to solve problems in a cooperative group setting without suffering losses in scores on standard achievement tests or on attitude measures. The prescriptive method for problem solving was the common denominator in this study and it might have enabled students to experience success in solving stoichiometric chemistry problems regardless of the classroom organization. However, it appeared that more advanced students rely less on a prescriptive method than do other students. For the least well-prepared students, even the prescriptive method was not enough to help them become successful problem solvers.

All three chemistry teachers were positive about the cooperative grouping strategy and indicated they intended to use it in all of their classes in the future.

THE USE OF CORE PROPOSITIONS IN SOLVING CURRENT ELECTRICITY PROBLEMS

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In order to investigate the nature of students' prior knowledge of current electricity and how they applied their knowledge to different problems, five middle school science teachers and eleven elementary school teachers were given a written test that required them to (1) predict what happens to the brightness of a bulb if a change is made to the circuit (a bulb is shorted or a second bulb is added in series or parallel), (2) compare the brightness of two bulbs in the same circuit, (3) compare the brightness of bulbs in different circuits, or (4) compare the amount of current at different points in a series or parallel circuit and (5) explain their reasoning for each question. The responses of the teachers to were systematically analyzed to determine the propositions they used as a basis for solving the problems and a matrix was formed of core propositions by subjects. From this matrix it was possible to determine the core propositions common to all teachers, as well as patterns of the different propositions held by different teachers.

The results of this study were useful in two ways. First, they supported our expectations about the nature of students' prior knowledge and how it is applied. Most of the elementary and middle school teachers in this study shared a common core of propositions that made up a coherent, but incorrect and not internally consistent, sequential model of current flow. They also had ideas of their own that were important to their performance. Furthermore, they did not simply apply their ideas in a mechanical manner. They adapted their thinking to the problem at hand, even when this meant that their solution to one problem was inconsistent with their solutions to other problems and that different propositions resulted in contradictions within a problem. Taken together these features of the students' knowledge and its use accounted for a very wide range of answers to the questions on the pretest.

Second, the results were applicable to the task of designing instruction for these students. The subsequent instruction was designed so that students were required to develop an understanding of current electricity that was internally consistent and that allowed them to make predictions which were consistent with their observations. The sequence of activities was based on the introduction of two competing fluid flow analogies. One of these reflected the core propositions of their sequential current model and the other reflected a correct model. The teachers were guided through a series of experiments to decide which model consistently accounted for all of the observed facts. The individual activities also were designed to account for specific correct and incorrect conceptions that the students brought to the instruction.

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TEACHER KNOWLEDGE AND TEACHER PLANNING: THE IMPACT OF SUBJECT-MATTER KNOWLEDGE ON THE SCIENCE CLASSROOM

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The curricular plans of four beginning biology teachers were analyzed as part of a study of the effects of teacher subject-matter knowledge on biology teaching. Using lesson plans as a principal data source, this paper reports that teachers' choices of instructional strategies were affected by their relative subject-matter knowledge. When teaching familiar topics, for example, teachers were more likely to conduct whole-class lectures and recitations -- discourse settings which are conversationally "risky" because they provide opportunities for students to ask questions which may challenge the teachers' understanding. In contrast, when teaching unfamiliar topics, teachers were more likely to rely on conversationally safe activities like student seatwork. Instructional decisions like these have repercussions for the portrayal of science as substance and process, and for the participation of students in classroom discourse. The study describes the development of a taxonomy of 29 activity types and the process of coding and validating 1186 activities over 650 biology lessons. Teacher subject-matter knowledge was assessed using several measures, including card-sort tasks, interviews, and analyses of teachers' undergraduate and graduate university transcripts. The results of the study were found to be generally consistent with complementary analyses of audiotaped classroom discourse.

THE INFLUENCE OF INTENSIVE INSERVICING ON PEDAGOGICAL CONTENT KNOWLEDGE GROWTH AMONG NOVICE CHEMICAL DEMONSTRATORS

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This study examined the influence of an intensive, inservice chemical demonstration workshop on fostering pedagogical content knowledge (PCK) growth among novice chemical demonstrators. Teachers use their PCK to make decisions on how to teach very specific subject matter topics to students of various ages and abilities. Although some research exists on the PCK of beginning teachers in English and social studies, a paucity of research currently exists regarding the nature and growth of this knowledge system among science teachers.

A clinical interview, consisting of a critical-stop task and a semi-structured interview, served to probe novice and experienced chemical demonstrators' pedagogical content knowledge. One elementary and seven secondary science teachers identified as novice chemical demonstrators volunteered for this study. The five workshop instructors served as experienced chemical demonstrators.

The novice chemical demonstrators participated in a two-week chemical demonstration workshop designed to improve their demonstration teaching skills. The workshop was carefully planned over a series of years by leading chemical educators and chemical demonstrators. The workshop allowed participants to receive direct instruction on effective chemical demonstrating as well as to observe, practice, perform, and receive feedback on numerous chemical demonstrations covering many basic concepts in chemistry.

The clinical interview focused on teachers' knowledge of the demonstration teaching of two basic chemical concepts: density and air pressure. The critical-stop task required subjects to view two videotaped chemical demonstrations and on the second viewing stop the tape at critical segments to make comments on what they perceived contributed to effective and ineffective chemical demonstrating. The semi-structured interview consisted of several questions on alternative chemical demonstrations on the targeted concepts. Novice demonstrators were interviewed prior to and at the end of the chemical demonstration workshop. The experienced demonstrators were interviewed before, during, and after the workshop as scheduling permitted.

A domain, taxonomic, and theme analysis and a quantitative content analysis was conducted on the verbal data. The data showed that an intensive, two-week chemical demonstration workshop produced an increase in the number of chemical demonstrations and demonstration variations novice chemical demonstrators could discuss on the targeted concepts, density and air pressure ($p < .05$). The novice demonstrators also became more cognizant of the complexity of several chemical demonstrations, how these complexities could interfere with learning, and how simplified variations of these chemical demonstrations could promote concept learning. After the workshop, novices' verbalizations could promote concept learning. After the workshop, novices' verbalizations also contained fewer references to pedagogically unsound chemical demonstrations on the targeted concepts. Each of these changes reflect characteristics of experienced chemical demonstrators' interview discourses. A content analysis revealed a change in focus from generic teaching issues to issues more closely aligned with pedagogical content knowledge; however, the number of critical incidents novices discussed during the critical-stop task remained the same.

This research provides empirical evidence that pedagogical content knowledge of science teachers can be substantially enhanced through intensive, short-term inservice workshops. Documenting PCK growth in science teachers is particularly important when trying to educate and re-educate teachers to fill science teaching positions with qualified elementary and secondary science teachers.

ACCURACY OF TEACHERS' KNOWLEDGE ABOUT STUDENTS' SCIENTIFIC THINKING

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Recent studies of teachers' thinking have indicated that some teachers have developed considerable knowledge about their students' scientific thinking, even in the absence of specific training directed toward that issue. However, little is known about the detailed nature of teachers' understanding of students' scientific thinking, and how much detailed knowledge is needed to be successful in monitoring student understanding and facilitating learning. This study addresses the accuracy of knowledge about students' conceptions of photosynthesis, cellular respiration, and matter cycling held by a sample of twelve middle school science teachers and how that knowledge was related to their ability to predict students' success in learning the concepts.

The teachers completed an interview task in which they predicted students' response to a series of diagnostic test questions. The teachers' predictions were compared to students' actual responses using a coding system developed to address important content issues embedded in each test item.

The results indicate that eight teachers possessed a range of detailed knowledge about their students' thinking about photosynthesis, cellular respiration, and matter cycling issues. Their predictors about the nature of student responses were generally consistent with the students' actual responses (approximately 60%-80% correspondence between issues addressed by students and predicted by teachers). The teachers' predictions about students' success varied from 5% to 100% according to the nature of individual test items. In general, these predictions were higher than students' actual performance, however differences between the researchers' goal responses as reflected in the test coding system and the teachers' goal responses may have attenuated those differences.

Four teachers' ability to discuss the nature of students' responses was often limited to guesses and "I don't know." Their predictions about students' success seldom focused on content issues. They made few statements about the relative difficulty of the science content addressed by individual test items. Their predictions of student success (often in the 80 - 90% range) were significantly higher than actual student performance.

This research provides significant insights into the nature of knowledge about students' scientific thinking held by experienced teachers, and illustrates the importance of knowledge about students' scientific thinking in helping teachers make accurate assessments about the progress of student learning. At the same time, it illustrates that such knowledge, while necessary, is not sufficient to ensure that students learn science with understanding.

THE EFFECT OF TRAINING CONTENT KNOWLEDGE AND STRATEGIC KNOWLEDGE ON ANALOGICAL REASONING AND DOMAIN KNOWLEDGE STRUCTURE

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Recent literature reviews on the role of domain knowledge and strategic knowledge acquisition and processing indicated that few studies had examined the interactive effect of domain and strategic knowledge training on performance. In this training study 121 grade 6 students were selected from an entire middle school on the basis of low pretest scores on a knowledge test of human biology, on a test of analogical reasoning, or on both. These groups were assigned randomly to training or to a nontraining control. Training consisted of three 50 minute sessions spaced over a week in which direct instructional methods were used to teach either domain content in human biology or analogical reasoning. The group low on both pretests received both kinds of training.

Results indicated that trained groups gained on parallel forms of the domain test but not on analogical reasoning, except for students low on both tests, who showed no gain. Qualitative analyses showed that students can be reliably categorized by the type of error they make, which differed between trained and untrained groups.

CHILDREN'S CONCEPTS OF SEASONS: A COMPARISON OF THREE INTERVIEW TECHNIQUES

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A great deal of work has been accomplished over the last ten or so years on children's conceptualizations of various scientific phenomena. A problem, however, is determining whether one's collection techniques provides a complete picture. In this study three techniques (the repertory grid, draw and describe, and the interview about events) were used to collect information on children's concepts of the seasons. Twenty-four fourth graders were included in this study. Eight children were interviewed using this technique. The relationship of "life-world knowledge" and "scientific knowledge" is critical in this study since seasons can be approached from the direction of scientific explanations or cultural events and celebrations.

The results indicate than one technique provided more of a science knowledge view, one technique provided more of a cultural view, and one technique provided a combined cultural/scientific knowledge view. The results suggest more of a relationship between school science and school social studies and may support the current Science-Technology-Society emphasis.

DIFFICULTIES EXPERIENCED BY SENIOR HIGH SCHOOL CHEMISTRY STUDENTS OF ELECTROCHEMISTRY: ELECTRIC CIRCUITS AND OXIDATION-REDUCTION EQUATIONS

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The purpose of this research was to investigate students' understandings of electrochemistry following a course of instruction. A list of conceptual and propositional knowledge statements was formulated to identify the knowledge base necessary for students to understand electric circuits and oxidation reduction equations. The conceptual and propositional statements provided the framework for the development of a semi-structured interview protocol which was administered to 32 students in their final year of high school chemistry.

The interview question about electric circuits revealed that several students in the sample were confused about the nature of electric current in metallic conductors. Students studying both physics and chemistry were more confused about current flow in metallic conductors than students who were only studying chemistry. It was postulated that this confusion was created by the fact that students studying both subjects were required to use two models for electric current; in chemistry students were taught that current was due to the movement of electrons and in physics students were taught about conventional current.

In this section of the interview which focused on oxidation and reduction, many students experienced problems when trying to identify oxidation-reduction equations. The major sources of error were when students attempted to identify the equations by using definitions of oxidation and reduction based on oxygen or electron transfer, instead of changes in oxidation number. Several misconceptions relating to the inappropriate use of definitions were identified.

Implications of the research for science curricula and science classroom practice were based on the results and interpretation of the interview data, and the misconceptions and alternative frameworks which identified. The implications relate to the relationship between physics and chemistry teaching; the treatment of electricity concepts in chemistry; students' interpretations of the language of science; inappropriate uses of models or theories; the distinction between knowing facts and understanding or applying principles and theories; the use of historical approaches to teach concepts; and teaching to improve students' understanding.

AN ANALYSIS OF STUDENTS' ERRORS ON AN EXAMINATION QUESTION THAT ASSESSED THEIR KNOWLEDGE OF THE RELATION BETWEEN THE ATOMIC/MOLECULAR AND MOLAR MASSES OF A SUBSTANCE

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The author's purpose was to identify and analyze students' errors on a chemistry examination question which assessed the nature of the relation between the mass of a single unit of matter in atomic mass units - the atomic/molecular mass - and the mass in grams of one mole of the same matter - the molar mass. Forty-eight (48) students who were enrolled in the first quarter of freshman chemistry for scientists and engineers at a large, urban, midwestern research university during summer quarter, 1988, were the subjects. The author incorporated into lectures special emphasis on construction of the relation between the molar mass of a substance and its atomic or molecular mass. One question on the first exam assessed the extent of students' understanding of this relation. Results indicate that

students' most frequent errors were: 1) defining the mole in terms of Avogadro's number rather than in terms of the number of C-12 atoms in 12 grams of C-12; 2) equating moles and atomic mass units, grams and atomic mass units, and moles and grams by the relation 1 = 1 or 1 = 6.02×10^{23}; 3) not constructing a logical argument that explained the relation by connecting its component parts. The results are discussed in terms of potential misconceptions that could cause such errors and in terms of improving students' understanding of the mole concept and its use in stoichiometry problems.

THE BOTANICAL CLASSIFICATIONS AND CONCEPTS OF STUDENTS PRIOR TO SEVENTH GRADE LIFE SCIENCE INSTRUCTION - AN ETHNOGRAPHIC APPROACH

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Research on students' scientific misconceptions point out the large discrepancies between concepts held by the child and concepts held by teachers and text. Studies often focus on abstract concepts and emphasize student deficiencies. More research is needed to ascertain the correct concepts, both abstract and concrete, that the child holds, as well as the misconceptions. Student strengths, as well as weaknesses, should be examined when planning a curriculum.

This research attempts to develop a portrait of the botanical folk classifications and concepts of students prior to studying botany in seventh grade life science. An ethnographic study was conducted in the spring and fall of one year.

A small sample of ten sixth grade students was interviewed extensively, in indoor and outdoor settings, near the end of the school year. A large sample of 234 seventh grade students completed a questionnaire at the beginning of the following school year. This sample consisted of all students taking life science in a small junior high school. The questionnaire served to check reliability of the responses from the small sample. The questionnaire also tested a number of hypotheses derived from analysis of the small sample data.

Data from both phases of the study support the following findings. Students lack appropriate labels for plants and plant parts. Simple terms (such as plant, leaf and petal) basic to learning botany concepts, had different meanings for different children, meanings which often conflicted with textbook meanings. When interviewed in an outdoor setting, children were frequently unable to apply these terms correctly. Students also exhibited limited knowledge of the functions of various plant parts (such as flower, leaf, pollen) and of plant processes such as food production and reproduction. These problems occurred with all children examined in the small sample.

In spite of these deficiencies, students exhibited a number of strengths. Some students gave detailed descriptions of plant specimens, demonstrating the abilities to (1) cue in on the many of the same characteristics that botanists use in plant classification, and (2) use multiple characteristics in plant classification. Some students exhibited well-developed and consistent definitions for broad categories of plants. The science process skills of observation, classification, and inference were well exhibited.

Large sample data allowed for examination of factors that may influence differential concept development among students. Chi-square analysis was used to examine the influence that the following factors may have on student concept and category use: male/female, rural/urban upbringing, indoor/outdoor orientation of the child, ethnic background, and aptitude test scores.

An overview of elementary science textbooks revealed that the curriculum tends to overlook those areas in which students could excel, such as basic skills used in plant classification, and emphasizes abstract concepts such as photosynthesis and reproduction, concepts requiring formal operational thinking. Because many teachers restrict the study of plants to the classroom, students do not gain practice in recognition of plants and plant parts. The lack of this basic knowledge may be a major stumbling block to overcoming misconceptions about botanical concepts.

INTENTIONS OF SCIENCE TEACHERS TO USE INVESTIGATIVE TEACHING METHODS: A TEST OF THE THEORY OF PLANNED BEHAVIOR

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The purpose of this study was to explore the utility of the Theory of Planned Behavior for predicting the intentions of teachers to use investigative teaching methods. In particular, the study investigated three determinants of teachers' behavioral intentions (BI) set forth in the theory of planned behavior, namely attitude toward the behavior (AB), subjective norm (SN), and perceived behavioral control (PBC). The behavior selected for purposes of this study was the intention of teachers enrolled in a summer institute for teachers of physical science, grades 5/6 and 9/10, to use 50 percent of the activities and investigations completed in the institute with students they would teach during the next school year.

Four constructs, central to the Theory of Planned Behavior, were examined: behavior (B), behavioral intention (BI), attitude toward the behavior (AB), subjective norm (SN), and perceived behavioral control (PBC). The constructs are functionally related through the equation,

$$B \sim BI \sim w_1AB + w_2SN + w_3PBC$$

where w_1, w_2, and w_3 are relative weights of attitude, subjective norm, and perceived behavioral control, respectively, to the prediction of behavioral intention and behavior.

Data were collected from 46 elementary and secondary teachers, using a questionnaire constructed from teachers' responses to previously administered open-ended statements regarding their attitude, social support, and perceived behavioral control. Direct measurements were made of behavioral intention, attitude toward the behavior, subjective norm, and perceived behavioral control. Simple and hierarchical regression analyses were used to determine the relative contributions of attitude, subjective norm, and perceived norm, and perceived behavioral control (and the interaction terms) to the prediction of behavioral intention.

Results of this study indicated that attitude, subjective norm, and perceived behavioral control made significant, linear contributions to the prediction of behavioral intention. Examination of the beta coefficients in the regression equation revealed the relative contributions of attitude, subjective norm, and perceived behavioral control to the prediction of teachers' behavioral intentions ($w_1 = .46$, $w_2 = .25$, and $w_3 = -.04$, respectively). Attitude toward the behavior proved to be the single most

important predictor of the behavioral intention in question, namely to use 50 percent of the activities and investigations completed in the institute with students whom teachers would teach during the next school year. Performance of the instructional behavior of interest in this study may be totally under the control of the teacher, with little need for social support and with ample resources and sufficient opportunities provided to perform the behavior.

CONCEPTIONS OF "GOOD" TEACHING AND LEARNING IN MIDDLE SCHOOL SCIENCE CLASSES

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The general question addressed in this ethnographic study is to understand conceptions of "good" teaching and learning from the perspectives of a teacher, students, and school administrators with regard to four major aspects of everyday classroom practices: (a) curriculum materials and instructional content, (b) classroom management, (c) personal relationship between the teacher and students, and (d) evaluation of teaching and learning outcomes.

Two eighth-grade science classes taught by the same teacher were involved in the study: one enriched class of high-achieving students and one regular class perceived as a "problem" class by the teacher. The teacher was a black female, who taught science for nine years out of her 11 years of teaching experience. Her college major was in social studies, and her minor was in science and mathematics. The school drew an ethnically mixed, primarily low to middle-SES student population in an urban school district. Data sources included: classroom observations; interviews with the teacher, students, and school administrators; curriculum and instructional materials; and school documents and announcements.

The data lead to four major assertions, representing different aspects of classroom teaching and learning as perceived by the teacher, students and administrators:

1) Teaching was perceived by the teacher as covering content and keeping students busy on "work," while learning was perceived by students as completion of work on time and the amount of work.
2) Teaching was perceived as keeping students quiet.
3) Teaching was perceived as maintaining good personal relationships between the teacher and students.
4) Students' grades were perceived as the measure of the outcomes of teaching and learning.

The findings seem to lead to four major conclusions with regard to the roles of teaching, learning, and supervision perceived by the teacher, students, and administrators:

First, the teacher seemed to define her roles of teaching as maintaining order in class and keeping students busy on their work, rather than fostering in them the learning of conceptual knowledge and skills.

Second, students seemed to perceive their roles of learning as completing work on time, rather than understanding of scientific content.

Third, administrators seemed to define their roles of supervision as maintaining the system of schooling, rather than helping the teacher and students with their teaching and learning activities.

Finally, consistent with their conceptions of teaching and learning, the teacher, students, and administrators all thought that they were essentially doing what they were supposed to do: getting the job done and maintaining the system.

It seems apparent that conceptions of teaching and learning held by the teacher, students, and school administrators in this study are inconsistent with conceptions of "good" teaching and learning generally defined in research. This raises questions about the system of schooling that allows the teacher, students and administrators to continue classroom practices when, at a deeper level, they know that there should be more to science education than was happening in these classes.

TEACHING INVENTIVENESS: A DEVELOPMENTAL PROGRAM

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Recently, an overlooked dimension in science education - the development of students' inventiveness - has been given national attention by the establishment of INVENT AMERICA program by the U.S. Patent Model Foundation. This program challenges our nation's youth to conceive and build original inventions for entry into a national competition. This movement raised questions that needed research answers: Can elementary children be expected to successfully contrive their own inventions? Can a training program effectively develop the skills of invention? Can "ordinary" classroom teachers foster children's inventiveness? Will children's attitudes toward science be changed if they are involved in an inventiveness training program? Are there gender differences in children in either innate ability to invent or in susceptability to training in inventiveness?

In order to find data-based answers to the above questions, an Inventiveness Training Program (ITP) was developed. The ITP consists of a series of activities focusing on visual thinking, humor, brainstorming, alternate uses of common objects, creative thinking, and inventions built from junk or commonly available inexpensive materials. This program was then implemented in five randomly selected sixth grade classrooms (n = 143). Five other randomly selected sixth grades were used as comparison groups (n = 152). Comparison group students experienced a "standard" textbook-based unit on simple machines during the three weeks in which experimental subjects were involved in the ITP. All of the classes used in the study were expected to participate in the INVENT AMERICA program as a regular assignment of their science programs.

Criterion instruments used for the study included the Science Attitudes Inventory (SAI; Morrisette), the Purdue Creativity Test (PCT; Lawshe and Harris), and the Invention Evaluation Instrument (IEI; Kuehn). The SAI and PCT were given to all subjects as pre- and posttests. The IEI, because it could only be used after students had completed inventions, was used only as a posttest.

Results

Gain scores from the pretest and posttest administrations of the PCT and SAI were compared using analysis of variance. Scores from the IEI were compared using the same statistical technique. The data collected support the following major interpretations:

1. Many sixth grade children have remarkable abilities to invent.
2. Children having the benefit of the ITP scored significantly higher on the IEI than those who received comparison group instruction. It appears that the ITP is very potent as an inventiveness-stimulator.
3. Males scored consistently higher than females on the IEI.
4. Treatment group students improved their attitudes toward science at a significantly higher level than did control group students.
5. A comparison of total group scores on the PCT found no significant differences in gain scores of creative thinking abilities, though means on various subscales were consistently higher in favor of the treatment group. However, when females only were compared, significantly greater gains were demonstrated by the females of the treatment classes. Females tend to score lower than males on pretests, but seem to respond more to treatment.

ENHANCEMENT OF TEACHER DECISION MAKING IN SCIENCE CLASSROOM LESSONS

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Successful science teaching involves many complex behaviors that require effective use of higher level thought and decision making processes. Recognition of the fact that novice teachers have cognitive and metacognitive deficiencies which effect the way they react to information available to them, and thus classroom decisions, should meaningfully influence the type of science teacher educatior provided. Developmental progress in intellectual processes as related to teacher thinking and teaching effectiveness was examined in the reported investigation. Antecedents and results of hypothetical-deductive reasoning in teacher decision making were linked to an intervention instruction program designed to increase ability in that area.

A pre-posttest research design, extending over 5 months, was used with 38 senior year preservice early and middle childhood teachers involved in a field-oriented block of methods courses. The study intervention treatment included instruction in specific data gathering processes of cue attendance, information search strategies, hypothesis generation, and designing strategies for hypothesis testing. Teacher performance (dependent variable) involved analyzing and writing science lesson plans, solving classroom problems during interactive computer simulations, analysis of classroom teaching episodes, and decision making in teaching classroom science lessons.

Significant changes were found with intervention instructed teachers' performance of basic skills involved in processing of information in analyzing and writing science lesson plans, analysis of classroom teaching episodes, and in teaching classroom science lessons. A comparison was made with performance of expert science teachers. Both intervention instruction and higher overall cognitive functioning level of the teachers supported more expert science teaching performance.

TEACHERS' VIEWS OF TECHNOLOGY: A RESEARCH REPORT

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This paper reports the results of a survey of 1,200 teachers' views on technology. Using a combination of empirical methods, teachers' responses to statements about technology in contemporary society were examined. The paper describes the following: new statements about technology based in the sociology of technology, teachers' responses to these statements, teachers' responses compared to those of high school graduates and undergraduate science students. As well, the paper speculates on the model of technology held by many teachers and offers suggestions for pre- and in-service education.

A series of statement pairs (positive and negative exemplars) were designed to elicit teachers' responses to the issues of technology and quality of life, technology and employment, technology and health care, technology and food production, and technology and social well-being. The responses indicated that the teachers in this sample describe and critique technology from an artifact perspective, that they are evenly split on whether technology improves employment prospects, that medicine is the example most often cited as an example of beneficial technology, and that a technocracy is favored by half the respondents.

These results are indistinguishable from the responses of graduating high school seniors. They suggest the need for an increased emphasis in pre-service education on the sociology of technology.

A QUALITATIVE ANALYSIS OF THE EFFECTS OF A MICROTEACHING COURSE ON PRESERVICE SCIENCE TEACHERS' INSTRUCTIONAL DECISIONS AND BELIEFS ABOUT TEACHING

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The microteaching course continues to be a focal point in the preservice training of science teachers. It is one of the few opportunities that the preservice teacher has to practice execution of instructional plans, develop instructional behaviors, view one's own teaching on videotape, and receive systematic feedback prior to the student teaching experience.

At present, there is yet to be any systematic, exploratory investigation of preservice teachers' beliefs, attitudes and perceptions about teaching, or their decision making skills within the context of a microteaching course. Given the prominence of microteaching courses within science teacher education programs, it is quite disconcerting that the effects of such courses have been ignored. The purpose of this investigation was to qualitatively investigate (so as to avoid any unsubstantiated a priori assumptions) the effects of a microteaching course on preservice science teachers' perceptions of teaching, instructional behaviors, decision making skills, and any changes in beliefs which occur throughout the duration of the course.

A total of 17 preservice teachers (15 males, 2 females) enrolled in a microteaching course constituted the sample for this investigation. Eleven were completing undergraduate degrees leading to teacher certification, while six were graduate students pursuing initial certification.

All students were required to plan and present four lessons of 15-20 minutes in length. Each lesson was videotaped and students were required to view and self critique their lessons. In addition, each student received both a formal written critique from the course instructors and an informal verbal critique from their peers following each presentation. Since one of the purposes of this research was to investigate any changes in the beliefs and perceptions of preservice science teachers toward teaching, subjects were required to complete a reaction questionnaire concerning such beliefs/perceptions prior to their first presentation as well as following each of the four required presentations.

A series of systematic, qualitative comparisons among students' comments on self critiques and reaction questionnaires yielded a total of 12 categories of concerns/beliefs about teaching common to the group. These categories "naturally" fell into two groups (i.e., Concerns for Self, Concerns for Students). Consistent with prior research, it appeared that the subjects in this investigation proceeded through a developmental process beginning with concerns for self and moving toward concerns for students. However, qualitative analyses of subjects' comments about students revealed that such comments were actually egocentric. Rather than commenting on students' learning, the subjects typically referred to students as though they were hinderances to the successful execution of the planned lesson. Finally, prior research has viewed planning primarily in terms of the mechanical construction of a plan. However, the data of this investigation indicate that such a conception is overly simplistic. Our subjects viewed planning as a two component process (i.e., the physical act of writing a plan and the subsequent mental rehearsal of that plan). Instruction in planning should attend to the significant process of "rehearsal."

SHORT-TERM AND LONG-TERM INCREASES IN CONFIDENCE LEVELS OF INSERVICED ELEMENTARY AND MIDDLE/JUNIOR HIGH SCHOOL SCIENCE TEACHERS

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The purpose of this study was to measure any change in the confidence levels of teachers who participated in the science inservice project. During a four-week intensive summer session, the 175 participants received two hours of specific science content information and three hours of instructional methodology daily. Pre- and post-measurements of participants' confidence levels for teaching science content, critical thinking skills, and in the use of varied teaching strategies were determined by a twelve-item Likert scale instrument designed by the authors of the study. These scores were analyzed for any significant change. Results indicated that both groups (elementary and middle/junior high teachers) reported significant gains in confidence levels in each of the three focus areas. During the ensuing academic year, the participants attended four follow-up sessions, two in the fall and two in the spring. The participants' confidence levels were again measured, using the same twelve-item scale, at the end of the last follow-up session. The post-posttest scores were analyzed for any significant increases with the pretest and posttest scores. Results indicated that increased confidence levels were sustained throughout the following school year. Statistical analyses conducted on each of the three focus areas of the instruction supported the aim of the project. Contrary to earlier findings, there were no significant sex differences in either teaching level with pre-, post-, or post-posttest scores.

THE EFFECTS OF A SUMMER INSERVICE PROGRAM ON SECONDARY SCIENCE TEACHERS' STAGES OF CONCERNS, ATTITUDES, AND KNOWLEDGE OF SELECTED STS CONCEPTS AND ITS IMPACT ON STUDENTS[1]

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This investigation was to determine the effects of a two week summer workshop on Science Technology & Society topics and methods of classroom implementation on the knowledge, attitudes and stages of concerns of the participating secondary inservice teachers as well as student impacts. This study was conducted using a modified pretest-posttest control group design. Participating teachers and their peers were pretested prior to two weeks (70 hrs) of instruction and posttested at the end. The participating teachers implemented a ten day STS unit into their traditional classrooms and pre- and posttested their students and the control group. Teacher knowledge was evaluated using an instrument designed by the investigators with content validity, test-retest reliability ($r = .84$) and an internal consistency estimate KR-20 ($r = .82$). The attitude instrument was designed by the investigators with content validity, reliability test-retest ($r = .77$), and internal consistency (KR-20; $r = .75$). The Stages of Concerns Questionnaire is an established instrument. Face validity was assumed for the teacher-made student achievement test. Covariant analysis was used to evaluate the effects of the treatment at the .05 level of significance. The participating teachers' ($N = 22$ exp. and $N = 17$ control) concerns were lowered as follows: Awareness ($F = 45.9$, $df = 1.36$); Information ($F = 11.8$); Consequence ($F = 16.9$); Collaboration ($F = 29$); and Refocusing ($F = 26.5$). These results were supported by the significantly greater scores on the achievement test obtained by the experimental group ($F = 115.2$, $df = 1.35$). Their Knowledge and Awareness levels of concerns were lowered as their knowledge increased. The attitudes of the teachers who participated were significantly increased in the direction judged to be positive ($F = 9.3$, $df = 1.35$) when compared to the control group. In addition, the students (intact classes $N = 11$) of the teachers who participated in the STS program achieved significantly higher scores on the teacher-made achievement tests than did the control (intact classes $N = 9$), ($F = 35.5$, $df = 1.17$). The results of this investigation indicate that a two week summer inservice workshop can be effective in reducing teacher concerns, increasing content knowledge and approach tendencies toward STS topics. In addition, this information was successfully transferred to the students of the participating teachers.

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ATTITUDES, BELIEFS, AND INTENTIONS TOWARD SCIENCE EDUCATION OF JUNIOR HIGH SCHOOL STUDENTS

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In recent years, considerable research has been conducted on prediction of achievement and participation in school science. It is generally recognized that the number of students who attempt science courses beyond the minimum required number is relatively small. Given the importance placed on scientific literacy in our society, there is great need for increasing the level of participation of all students. This study is an attempt to develop a tool for identification of the degree to which students will participate in future science courses.

The study being reported was conducted as an initial investigation of predictive power of the relationship between the components of an attitude suggested in recent social psychology research. That research describes an attitude as consisting of three components: affective, cognitive, and behavioral. Further, research has shown that consistency between the affective and cognitive components of an attitude will provide a higher predictive capability with regard to behavior or intention to behave.

An instrument was developed and administered to 150 seventh and eighth grade students. To determine whether differences in intention toward school science could be predicted, the respondents were sorted into consistency groups. Membership in the "consistent group" was given to those repondents whose attitude and cognitive scores were within one point of each other on the five point Likert response scale. Those respondents who did not meet this requirement were placed in the inconsistent group. Categorization into groups based on the degree of consistency led to higher levels of correlation for the relationship between the components of the attitude. For the relationship between affective and behavioral components of attitude toward science, the magnitude of the correlation differed from 0.16 for the inconsistent group to 0.56 for the consistent group. Similarly, the cognitive/behavioral components differed in the magnitude of the correlation with regard to attitude toward science for the consistency categories, with the inconsistent group having a correlation of 0.28 and the consistent group have a correlation of 0.51. Long term studies are being initiated to assess the predictive power of the technique with regard to the level of participation in school science.

THE DEVELOPMENT AND VALIDATION OF AN INVENTORY TO MEASURE STUDENTS' ATTITUDES TOWARDS SCIENCE FIELD TRIPS

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The wide acceptance of the importance and educational effectiveness of field trips in the context of science learning in general and in geological education in particular is well established. On the other hand, very little is known concerning the factors that affect students' attitudes and perceptions towards learning field trips. An attitude inventory was developed. The inventory was content validated and factor analyzed. Five factors convering 50 percent of the total variance were obtained.

- the learning factor
- the social factor
- the individualized factor
- the adventurous factor, and
- the environmental factor.

On the bases of the factor analysis it was concluded that attitude towards a field trip is not unidimensional. It was also found that the inventory is sensitive to grade and gender differences.

It is suggested that this inventory is an important tool for a comprehensive evaluation of field trips conducted in science in general, and geological education in particular.

CLARIFICATION OF THE DIRECTION OF THE AFFECT - ACHIEVEMENT RELATIONSHIP IN SCIENCE

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This paper examines the direction of the relationship between science-related affect and science achievement. Science-related affect is defined in broad terms, and has its theoretical base in Bloom's theory of school learning. The conceptual model for science-related affect proposes that students' enjoyment in and enthusiasm for science are determined by their perceptions of past performance in science, their expected future performance in science, and the perceived usefulness to them of science at school. It is hypothesized that science-related affect has an interactive relationship with achievement in science.

Data were collected from 342 Grade 8 students in their first year of high school at two urban middle class schools. Students studied three topics in each of the three terms of the academic year. Two measures of science-related affect were made, the first during the middle topic of first term, and the second during the middle topic of the last term. Students' achievement was measured by the usual school tests given at the end of each science topic. Previous and subsequent achievement were measured, respectively, by the tests on the topics completed before and after affect was measured. The relationship between affect and achievement could thus be tested on two occasions in each of the two schools. Multiple linear regression was used to examine the direction of the relationship between science-related affect and achievement and to apportion variance common between previous and subsequent achievement and the components of science-related affect. It was found that affect is related more strongly to previous than to subsequent achievment, and that much of the common variance can be attributed to students' perceptions of their competence in science.

THE EFFECT OF A PROBLEM SOLVING INSERVICE PROGRAM ON THE CLASSROOM BEHAVIORS AND ATTITUDES OF MIDDLE SCHOOL SCIENCE TEACHERS

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Teachers are exposed to many varieties of inservice education throughout their careers. It is critical to evaluate the success of such programs. One criterion of success must be the degree to which teachers effectively implement what they have learned.

This study examined the effects of an inservice education program emphasizing problem solving on teacher attitudes toward teaching science and on teaching behaviors. Twenty-two middle school science teachers participated in the program and another twenty-two served as the control group. The two groups were similar in terms of sex, teaching status, educational background, and professional activity during the treatment period.

Before and after the ten-month project, subjects completed attitude surveys and recorded videotapes of themselves teaching science lessons. No difference was noted between the groups on the attitude measure, The Science Teaching Attitude Scales.

The videotapes were analyzed using a coding scheme developed for use in this study, "Teacher Observations during Problem Solving." The system allows an observer to look at the class setting (whole class/small group/individuals), the stage of the lesson (from problem finding through evaluating), and the particular initiating or responding behavior used by the teacher.

A multivariate analysis of variance performed on the observational data showed a significant difference between the groups, with a greater difference noted after the workshop than before. The experimental teachers appeared to be shifting to more student-centered classrooms. For example, on the post-workshop observation they spent more time identifying problems and sharing conclusions, implying transfer of some responsibility to students. Also, these teachers substantially decreased the percentage of time spent on lecture and procedural talk and increased the time spent observing and listening to students. This shifting of the control of learning to the students is essential to developing student thinking and problem solving skills.

Teacher change in response to an innovation in education is a complex issues. Attitudes toward teaching can be very difficult to measure and to influence, as in this study. Notwithstanding such difficulties, this study provides evidence that an extended inservice education program can affect the teaching behaviors of science teachers in the middle grades.

IMPLEMENTATION OF A PROBLEM SOLVING CURRICULUM IN ELEMENTARY SCIENCE: CASE STUDIES OF TEACHERS IN CHANGE

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The problem solving mode of teaching science implies change for teachers, administrators, state education departments, and other individuals charged with implementing educational innovation. This multi-case study provides a descriptive record and interpretation of the words and actions of three elementary school teachers beginning to learn about teaching science as problem solving rather than dispensing content information, and attempting to modify their teaching accordingly. Data collection spanned a period of one year and included classroom observations, interviews, and document analysis.

Observations revealed that environmental factors such as administrative support and flexibility, availability of science materials, school philosophy, parental support, and teacher status strongly affected teachers' efforts to change. Personal or internal factors also influenced teachers' classroom practice: background in science, ability to see interdisciplinary teaching possibilities, organizational ability, regard for individual student's ideas, need to maintain control over student activities and thinking, personal reflectivity, regard for other teachers' intelligence and experience, emphasis on success, need to "cover" a textbook, understanding of the relationship between science content and problem solving, and general openness to change.

Because the subjects and their contexts differed, problem solving was handled differently by each of them. The first subject maintained a clear distinction between "science" and problem solving. Science was the content covered via a textbook, problem solving, the supplementary learning of inquiry skills. This teacher's strong background in science made her confident of what was factually correct; her need to be successful caused her to maintain tight control in order that the students got it right. The second subject, having experienced a personal liberation through coming to understand "discrepancies" rather than errors, grew to feel more comfortable teaching science and was attempting to problem solve with her students. The third teacher, while allowing her students a great deal of the independence necessary for problem solving, failed to provided clear direction and purpose for the use of available materials.

By calling attention to personal and contextual realities that influence outcomes, this study demonstrates that educators cannot control "results" merely by altering input. Acknowledging this is an important step in transferring responsibility from innovators of change to recipients.

FACTORS IN THE DEVELOPMENT OF REASONING IN TWO PROBLEM CONTEXTS

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This study had two major foci. First, it tested the predictive power of cognitive variables from two neo-Piagetian theories, i.e. Pascual-Leone and Case, on several aspects during the development of formal reasoning strategies. A priori hypotheses linked the dependent variables of amount of practice needed to induce problem solving strategies, transfer, and choice of problem solving behaviors after feedback to the independent variables of M-space, field-dependence, and short-term storage space. Second, the data were to be searched for specific behaviors and behavior patterns during this development. The subjects consisted of students enrolled in Physical Science I, a science course for non-science majors at the University of Southern Mississippi.

A pretest containing ratio problems in different contexts was used to identify those students who do not use the ratio scheme at the formal operational level. These students participated in a treatment which consisted of ratio problems in two contexts, the probability of drawing objects from a box and the balance beam. The problems were presented via computer programs which also provided feedback.

The data analyses showed that M-capacity and field-dependence, alone or in combination did not predict the amount of practice students needed to induce successful behaviors in either context. Also, contrary to other findings, field-dependence is not a predictor of either ability to transfer behaviors to new contexts or the re-use of unsuccessful strategies.

Short-term storage space, not a successful predictor of practice on probability problems, showed high correlations with transfer ability, choice of behaviors after feedback, and with the amount of practice needed on balance problems. On the balance beam, most non-formal students induced the product-moment rule was the strategy. There existed also significant differences on the cognitive variables between those subjects using the ratio scheme versus those who used the product-moment rule. In particular, students using or inducing the ratio rule have a ratio span of 4 or higher.

The data also suggest that students who monitor their activities during problem solving or who actively searched for patterns were developing effective behaviors faster than those students who did not. The findings in this study have been used to successfully construct computer-generated homework in physical science for students from the same population.

PROBLEM SOLVING BEHAVIORS AND APPROACHES OF SUCCESSFUL AND UNSUCCESSFUL SUBJECTS DURING INTERACTION WITH A GENETICS COMPUTER

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The study of Mendelian genetics is an integral part of the curriculum in introductory biology courses at secondary and post-secondary levels. Results from previous genetics learning studies and needs assessments demonstrated the need for more intensive research in biology education in general and genetics learning in particular. General problem solving behaviors and approaches employed by successful and unsuccessful subjects were examined during interaction with a genetics computer simulation. Thirteen subjects (geneticists and advanced biology students) investigated various hypotheses on genetic traits. Subjects' behaviors and approaches in an instructional environment based on learning cycle organizer were sampled during the exploration phase.

Successful subjects exhibited the most complex patterns of problem solving behaviors and used more purposeful strategies to investigate and determine inheritance patterns. Successful subjects described and reviewed their observations about the data. They also employed approaches which allowed them to eliminate particular explanations, to generate large sample sizes, to speculate about the fit between their data and the problem statement, and to focus and pursue more relevant data patterns. An intermediate group of less successful problem solvers exhibited some of the problem solving behaviors and approaches of successful subjects. Unsuccessful subjects exhibited more random approaches during problem solving than did other subjects. These subjects tended to overlook cues within the data patterns and to continue pursuing unfruitful avenues toward problem resolution.

This research study provided a rich source of information about cognitive processes of learners engaged with instructional software. Research studies can examine the development, evolution, and interaction of genetics concepts during various phases of hypothesis testing. By examining the options subjects select during problem solving, researchers can gain greater insight into the mental mechanisms and mental models learners construct and employ to explain underlying data patterns. Investigations which examine learners' conceptual development in topics studied in secondary and university level course, problem solving, and teaching models and instructional strategies are important subject for further research in science education. By examining the problem solving behaviors and concepts used by learners, the science education community can build a stronger empirical foundation from which to respond to relevant instructional needs of students and to understand the nature of problem solving and concept development.

INQUIRY SKILLS OF TENTH GRADE BIOLOGY STUDENTS IN A COMPUTER-ASSISTED LEARNING SETTING

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The purpose of this study was to compare the enhancement of inquiry skills of tenth grade biology students who received instruction in a traditional classroom-laboratory setting combined with computer assisted learning (CAL) with students who only received instruction by the classroom-laboratory method.

The sample consisted of 182 students in five 10th grade classes which were randomly assigned to the experimental and control groups. Three classes (N = 101; 84 girls and 17 boys) formed the experimental group (those receiving CAL instruction) and the other two classes (N = 81; 65 girls and 16 boys) served as the control group. Both groups were taught by the same three biology teachers who were assisted by a laboratory assistant and a microcomputer aide.

All students studied the same topic, the impact of temperature, nutrient concentration, and the initial number of individuals on the growth rate of a population of micro-organisms. While the laboratory work allowed students in both groups to perform experiments in which the effect of each factor was investigated separately, students in the experimental group were able to assess the simultaneous impact of the three factors through inquiry-oriented, computer-simulated experiments specially developed for this study. The combination of CAL and classroom-laboratory modes enable students to operate at higher cognitive levels which may enhance their inquiry skills.

The study was conducted over a four-week period with students attending three 45-minute classes each week.

An instrument measuring inquiry skills, which contained 48 multiple choice questions divided into nine subscales, was administered before the students began studying the topic and at its conclusion. The content of the test was validated by five high school biology teachers and received an alpha CRONBACH reliability in a range from .73 to .79 for the nine subscales. Data were treated by analysis of covariance.

The experimental group scored significantly higher on the posttest on the following three subscales: graph communication, interpreting data, and controlling variables. No differences were found between boys and girls in the experimental group.

While the mean scores of boys in the experimental group and control group were different but not significantly so, the mean scores of the girls in the experimental group were significantly higher than those in the control group on two subscales: interpreting data and controlling variables.

The control group performed significantly higher on only one subscale, prediction.

The results of this study suggest that inquiry-oriented CAL can enhance the inquiry skills of biology students when used as a supplement to a classroom-laboratory mode of instruction where inquiry skills are also emphasized. By facilitating individualized learning, CAL can be an especially effective tool in helping girls achieve at higher cognitive levels.

VIDEODISC BASED MACROCONTEXTS FOR INSTRUCTION: AN EXPERIMENTAL STUDY IN ELEMENTARY SCHOOL SCIENCE

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Most researchers and educators agree that an important goal of education is to help students learn to think for themselves and to solve problems. This emphasis on critical thinking skills has focused attention on the processes of thinking. However, research demonstrates that students' content knowledge--their knowledge of concepts, principles, and procedures--is also very important for effective thinking. An important challenge for science educators is to teach relevant content in a way that also facilitates independent thinking and problem solving.

One goal of the paper is to discuss the need for changes in current educational practice and to explore how videodisc macrocontexts can help teach content in ways that promote critical thinking. Previous studies using macorcontexts in science instruction have shown that the macrocontext approach can have positive effects on students' ability to use science information in problem solving situations.

The study to be reported is part of a larger project involving reading, writing, vocabulary, social studies, and science instruction where the macrocontext procedure was implemented across a full year of two fifth grade classes. Random assignment of forty-eight students to either experimental or control groups was stratified according to performance level on the Stanford Achievement.

A macrocontext based upon the film Young Sherlock Holmes was used with a science unit on simple machines. The students' science text contained a unit in this area with typical text, questions, and laboratory experiences. The supplemental macrocontext based materials developed were integrated into the presentation of the text. Appropriate video segments were identified for various sections of the unit. For example, a short scene that showed Young Sherlock using a ramp (inclined plane) was found and used to start the instruction on this simple machine. Students in the experimental group, as in the other studies, were shown the video segments while the control group did not use the video. Both groups did readings from the text, experiments suggested in the text, and additional demonstrations and experiments prepared for the unit by the experimenters.

Students were pretested on knowledge of simple machines by a simple identification and use instrument. Post unit instruments included knowledge and comprehension type items to test for basic understanding of simple machines as well as instruments intended to test student understanding of how these machines are important and how they are used today. Preliminary analysis indicates modest differences favoring the experimental (video) group on basic knowledge items and larger differences on the instruments used to measure applications knowledge.

THE USE OF A MICROCOMPUTER-BASED CLASSROOM SIMULATION IN THE PREPARATION OF SECONDARY SCIENCE TEACHERS

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The purposes of the study were: (1) to develop a microcomputer classroom simulation which could provide prospective secondary science teachers with laboratory experiences in classroom management; (2) to study the impact of the simulation on prospective teachers; (3) to compare experienced science teachers in Taiwan with those in the United States regarding their options toward the selected strategies and problems; and (4) to determine if the simulation results had different effects on prospective teachers of different cultural backgrounds.

A group of experienced secondary science teachers was asked to evaluate the selected classroom management strategies and discipline problems. Their mean responses served as a basis for the development of the microcomputer simulation.

The subjects involved in the study were students who enrolled in a secondary science methods course at The University of Michigan and the National Taiwan Normal University. They were divided into two groups: 1) a treatment group, and 2) a control group. Subjects' opinions of the classroom management strategies and problems were pre-tested, mid-tested, and post-tested, using the Instrument for Assessing Teachers' Perceptions of Selected Classroom Management Strategies and Discipline Problems (IATP). The student teaching behaviors were studied by asking the student teachers to report how they allocated teaching time and asking the supervising teachers to evaluate the teaching competency of the student teachers. In addition, the researcher observed the student teaching and examined the lesson plans prepared by the student teachers.

Data gathered were analyzed using the SPSSx computer statistical package to test the constructed hypotheses.

Several conclusions were drawn from the study: (1) The simulation provides prospective science teachers with an opportunity to practice classroom management. It can assist students in making judgments of classroom management strategies similar to those of inservice teachers. (2) The mean responses of the American and the Chinese teachers were different on certain strategies and discipline problems. (3) The simulation results had less impact on the American students than on the Chinese students. (4) The simulation did not result in differences in teaching performance between the American experimental groups. (5) The treatment group subjects expressed positive attitudes toward the microcomputer simulation.

The study has shown that microcomputers can be used to create simulations that allow users to practice decision-making similar to the decision-making occurring in the science classroom. Instructors of science methods courses should consider the use of microcomputer classroom simulations as instructional aids for teacher preparation. Additional recommendations related to future research and development of microcomputer simulations were made.

THE MATERIAL CULTURE OF FOUR ELEMENTARY SCHOOL SCIENCE CLASSROOMS: ENVIRONMENT AND MEANING

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The purpose of this study was to describe some ways in which the material culture in elementary school classrooms can contribute to children's understanding of the meaning of science. For the purpose of this investigation, a classroom's material culture was said to include the instructional materials, equipment, displays, decorations, and other physical features existing there. Four elementary classrooms were visited repeatedly by two observers during a single academic year. The objects and physical arrangements existing in each classroom for science instruction were documented through maps, inventories, photographs, and fieldnotes. During interviews, all of the teachers and selected pupils were asked to explain the significance of various science materials, displays, and areas used by each class. It was concluded that the material culture of the elementary classroom can communicate important massages to pupils about the nature, content, and value of science. Teachers knowingly and unknowingly use classroom objects and physical arrangements as silent contributors to their instructional programs. In this study, the messages communicated by the classroom environments included the relative importance of various science topics; the importance of science itself compared to other fields; the attractiveness of science; the relative importance of actively doing science, rather than passively learning about it; science work habits; and appropriate group size when doing science. It was suggested the results of studies such as the present one could be used to increase preservice and inservice teachers' awareness of the potential affect of the classroom's material culture on instuctional messages in science. It was also noted that the use of photographs, maps, and other visual prompts during teacher interviews seemed to stimulate the teachers to reflect on ways to improve the instructional value of their own classroom's material environment.

THE EFFECTS OF SELF-GENERATED EXAMPLES ON ELEMENTARY SCHOOL STUDENTS' RETENTION OF SCIENCE CONCEPTS

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The current study tested the effectiveness of having fifth-grade students generate their own examples of selected concepts studied in a three-week science unit on energy. Hypotheses were that subjects would perform better on sections of a test related to definitions and recognition of exemplars of the concepts for which they found their own examples than on sections related to comparible science concepts for which they did not generate examples.

Subjects were 26 fifth grade students enrolled in a university laboratory school. During the three-week unit on energy, students generated their own examples of thirteen energy concepts being studied.

A 2 (pretest vs. posttest) x 2 (generated vs. non-generated examples) x 2 (multiple-choice definitions vs. exemplars) repeated measures ANOVA was employed to test the hypotheses. There was no statistically significant effect for the treatment condition (generated examples) versus the control condition (non-generated) examples, but there was a statistically significant effect for the definitions section of the test, $F(1.24) = 12.28$, $p. < .002$. Subjects performed better on the section of the test related to definitions of concepts for which they had found examples than on the section related to definitions for which they had not found examples.

Results confirm the hypothesis that elementary school science students recall concepts for which they generate their own examples better than concepts for which they do not. Apparently, the process of finding and recording examples of concepts, and the attendant thinking about the concepts while seeking adequate examples, strengthens knowledge of the concepts themselves more than simply adding further examples of the concepts to the children's long term memory.

THE EFFECTS OF INTENSIVE INSTRUCTION IN CUE ATTENDANCE UPON ELEMENTARY SCIENCE EDUCATION PRESERVICE TEACHERS' INTERACTIVE THOUGHT PROCESSES: A QUALITATIVE STUDY

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Teaching has been described by a number of educational researchers as a complex activity. In an effort to enhance the knowledge base for elementary science teacher effectiveness, this study investigated the interactive inquiry thought processes of preservice teachers intensively instructed in cue attendance. Fourteen preservice teachers enrolled in education courses of a major mid-western university were randomly assigned to either a treatment or control group. Stimulus response procedures were utilized to obtain teachers' interactive thought process data. These data reflect the teachers' interactive thoughts when presented with a scientific phenomenon and asked to perform inquiry tasks (i.e., cue attendance, information search, and hypothesis generation). Intensively instructed subjects performed better in inquiry skill tasks than those subjects receiving no intensive instruction. Intensively instructed subjects also reported fewer references to knowledge from past experiences during inquiry skill tasks than did the control group. This suggests treatment could improve an individual's ability to generate additional relevant details and a willingness to consider alternative solutions when presented with a scientific phenomenon. Another way of interpreting the results is that intensive instruction training could improve an individual's ability to solve problems associated with scientific phenomena by allowing the subject's schema to accomodate alternative ideas, thus reducing the individual's reliance on pre-existing concepts and the individual's resistance to concept modification.

A COMPARISON OF PERFORMANCE-BASED VERSUS PENCIL AND PAPER MEASURES OF SCIENCE PROCESS AND REASONING SKILLS AS INFLUENCED BY GENDER AND READING ABILITIES

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Historically, paper-and-pencil tests have been developed in order to assess large numbers of students simultaneously. These tests have been validated by correlating them with other measures for the same construct. Several studies in recent years have focused on the effects of test mode in the assessment of basic process skills. The findings have been mixed and do not strongly indicate a mode which is far better than others.

Two modes which have been used in studies are paper-and-pencil tests and performance based tests. Although paper-and-pencil tests offer the advantage of convenience and usually require little or no special training to administer them, a number of problems can be associated with the exclusive use of paper-and-pencil tests as opposed to interview or performance tests.

The purpose of this study is to compare the relative results of middle school students being assessed on performance based tasks and paper-and-pencil tests. The desired product would be an enriched database of information on the attainment of program or instructional objectives. Specifically the study focused on two questions: (1) Will the scores from the two test modes be highly related?; and (2) Will the apparent difficulty level of the paper-and-pencil test differ from the performance test?

Middle school students from a Georgia school district (n = 1250) were administered paper-and-pencil tests on logical reasoning ability and process skills. Sixty-four students, selected by stratified random sampling, were then assessed on the performance based tests which paralleled the two paper-and-pencil tests. On the performance tests students were objectively scored following protocols developed by the research team.

The data analysis indicated the two testing modes were highly related with a correlation coefficient of approximately .80 on both the logical reasoning and process skills dimensions. However, the testing modes were found to differ significantly in difficulty although one mode was not consistently more difficult than the other. The logical thinking written test was more difficult than the logical thinking performance test indicating that reading may have masked the measurement of the logical reasoning construct. The process skills performance test was more difficult than the written process skills test, presumably due to cues on the written test. In spite of the seemingly contradictory results, the researchers believe this is also indicative of the performance based test being a more sensitive measure of the construct than the written test.

Special Session

AWARDS PAPERS

Each year NARST members who have presented a paper at the previous year's NARST annual meeting are invited to submit copies of their paper for consideration for the NARST Outstanding Paper Award or the Practical Applications of Research Award. (The recipient(s) of the Practical Applications of Research Award are invited to present their paper to a new audience: those persons attending the National Science Teachers Association's annual meeting.) The recipient(s) of the NARST Outstanding Paper Award are invited to present their paper (again) to NARST members attending this annual meeting.

Also, each year, the JRST Awards Committee reviews all of the papers published in the previous year's volume of the Journal of Research in Science Teaching and selects the outstanding published article. The recipient(s) of the JRST Award share this session with the NARST Outstanding Paper and present the findings from their award-winning article.

Special Session

ANNUAL REVIEW OF RESEARCH FOR 1987

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Each year NARST, in cooperation with the ERIC Clearinghouse for Science, Mathematics and Environmental Education, commissions a comprehensive review of research published during the preceding year. This review is published in Science Education. John Staver and faculty from the Center for Science Education at Kansas State University recently completed the review of research in 1987. This session will highlight some of the findings from this survey of the literature.

NARST Monographs

A THEORY OF INSTRUCTION: USING THE LEARNING CYCLE TO TEACH SCIENCE CONCEPTS AND THINKING SKILLS

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LEARNING ENVIRONMENT RESEARCH IN SCIENCE CLASSROOMS: PROGRESS AND PROSPECTS

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Acting on the recommendation of the Publication Advisory Committee, chaired by Ron Good, the NARST Board of Directors announced, at the 1988 annual meeting of NARST, that NARST would entertain the publication of a monograph on some science education research topic of interest to both established researchers as well as those just beginning their research careers. Not one, but two, monographs were developed for publication. This session will be devoted to a discussion that highlights the contents of both monographs.

Symposium

TOWARD A UNIFIED CONCEPTION OF THINKING, METACOGNITION, COGNITIVE DEVELOPMENT, INTERACTIVE-CONSTRUCTIVE LEARNING AND SCIENTIFIC INQUIRY

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The Information Age has been shaping the conception of thinking in education through the capability of computerized problem solving, through the resulting application of the information processing model to human thinking, and through the theories emerging from other cognitive science research in metacognition, construction of knowledge, and scientific inquiry. The potential of these recent efforts may not be fully realized since most researchers treat - and most of the literature reports - these new ideas in isolation and approach global thinking abilities as fragmented skills that are distinctly different or mutually exclusive.

Current developments related to the conception of thinking appear to be vacillating between applying models derived from cognitive science research, applying models generated from school traditions of isolated disciplines, or applying memories of the good old days. Until recently the focus of thinking instruction has usually been on the imposition of discipline-specific skills models based on classical problem solving, traditional logic, and contrived issues. What seems to be emerging in different areas of research in education is a need to go beyond these fragmented and traditional discipline models to facilitate students' search for, description of, and explanation of underlying principles and patterns; and to encourage students to be engaged in integrating thinking about their thinking with interdisciplinary knowledge that is worth thinking about.

Stimulating thinking, in spite of the concerns expressed by Bloom, Cheney and Hirsch, will be education's logo of the 1990s. Costa asserted "that the results are disappointing when we teach content alone in the hope that students will also learn to think." He also warned that "the teaching of thinking skills in isolation is just as unproductive." The information explosion and the ready access to massive quantities of information support the need for developing thinking that assesses the quality of the information. Paul pointed out that it was important to promote "critical thinking that encouraged people to think about their thinking as they are thinking to improve their thinking." de Bono cautioned the reader regarding the fragmentation of his thinking hats metaphor and included the white thinking hat as an executive function to monitor and to integrate the thinking results of the other five thinking hats. The New Jersey Basic Skills Council recommended the integration of thinking skills into four umbrella clusters, to unify a school's instructional efforts across disciplines and to consider real-life thinking as well as the traditional, abstract, critical, systematic, and precise thinking.

This symposium is organized to provide background on the fragmentation of thinking, alternative models of thinking, potential unifying principles and patterns underlying thinking and attempts to generate a unified conception of thinking. The central issue will be reflected upon from various psychological perspectives (cognitive science, cognitive development, metacognition, and interactive-constructive learning) and practical perspectives (instructional practices and assessment techniques). The symposium will also consider potential research questions related to a unified conception of thinking.

Symposium: Microcomputer-Based Laboratories

LEARNING WITH MICROCOMPUTER-BASED LABORATORIES: SCIENCE KNOWLEDGE AND EXPERIMENTATION

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This symposium brings together research on learning with Microcomputer-based Laboratories (MBL) from two institutions that have been working in the area for several years. The focus of this presentation is on the types of learning that occur when students engage in scientific study using MBL. The goal of the symposium is to explore the relationship between cognitive outcomes and the process of scientific experimentation that is facilitated by the use of MBL.

A growing body of evidence demonstrates that the use of MBL in science classes can have a beneficial effect on student understanding of science concepts, on student graphing and graph interpretation skills, and on student motivation. The current research builds on these findings in order to develop a better understanding of student cognition in MBL classrooms.

Two types of outcomes will be discussed: 1) depth of understanding of thermodynamics concepts by students who have used the MBL Heat and Temperature unit, and 2) level of understanding of scientific experimentation exhibited by students who engaged in MBL-based activities.

Four speakers will briefly present summaries of research investigating student learning with MBL. The four presentation are entitled:

1) "Assessing Depth of Knowledge: Performance of Students Using Microcomputer-based Laboratories on NAEP Thermodynamics Items" (Nancy Butler Songer, Marcia Linn)
2) "Heat Energy and Temperature Concepts of Adolescents, Naive Adults, and Experts: Implications for Curricular Improvement" (Eileen L. Lewis, Marcia Linn)
3) "Effects of Microcomputer-based Laboratories on Students' Understanding of Scientific Experimentation" (John P. Zuman, Hyoshin Kim) and
4) "Learning to Design Response Time Experiments with Microcomputer-based Laboratories" (John P. Zuman, Amy S. Weinberg).

Content and process in science are inexorably linked, and these four pieces of related research are examples of some of the ways these complex links are manifested when students use MBL.

Research Seminar

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This research seminar provides NARST members with an opportunity for further interaction with Martin Maehr related to the topic of his general session address: "It's Not Only What You Know, But Also What You Want to Know That Counts."

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